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Ecology of Elk in the Pine Ridge Region of Northwestern Nebraska: Seasonal Distribution, Characteristics of Wintering Sites, and Herd Health

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ECOLOGY OF ELK IN THE PINE RIDGE REGION OF NORTHWESTERN NEBRASKA: SEASONAL DISTRIBUTION, CHARACTERISTICS OF WINTERING SITES, AND HERD HEALTH

by

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ECOLOGY OF ELK IN THE PINE RIDGE REGION OF NORTHWESTERN NEBRASKA: SEASONAL DISTRIBUTION, CHARACTERISTICS OF WINTERING SITES, AND HERD HEALTH

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Twenty-one female elk (Cervus elaphus nelsoni) were located 5,789 times in the Bordeaux and Hat Creek study areas from April 1995 to August 1997. We identified two distinct, nonmigratory elk herds with annual home ranges that averaged 48,398 ha for the Bordeaux and 44,035 ha for the Hat Creek study area. Seasonal home ranges varied from 1,821 ha to 4,258 ha in winter, 2,887 ha to 4,165 ha in spring, 982 ha to 2,077 ha during calving, 1,574 ha to 4,408 ha in summer, and 1,976 ha to 4,408 ha during the breeding season. Cropland areas within winter range sites were used three times more than expected, considering their availability in both study areas. Spring home range areas shifted to forested habitat. Ponderosa pine habitat was used nearly two times more than expected, considering the availability in calving areas. Elk used agricultural fields five times more than expected, considering the availability on summer range. Elk used cropland areas five times more than expected, considering the availability during the breeding season. They avoided pasture areas with cattle present.

Twenty-one winter elk-use sites were identified in the Bordeaux and Hat Creek study areas- all were located on privately owned land between January and March of 1996 (n = 13) and 1997 (n = 8). Eighteen habitat variables were measured in the elk-use

sites and 44 randomly-located sites to evaluate elk habitat selection. We generated 72 logistic regression models to obtain the relative probabilities of individual elk selecting use sites over randomly-located sites. The model that best described winter elk habitat selection (Akaike's Information Criterion [AIC] = 70.7) included the variables: road type (two track, gravel, highway, or logging road), slope, and distance to edge. The second best fitting model (AIC = 72.5) included road type, slope, distance to edge, and hiding cover. Odds ratios for both models suggest that elk prefer winter areas that provide increasing slope ($\bar{x}$ = 16%, odds ratio = 1.225), distance to edge ($\bar{x}$ = 286 m, odds ratio = 1.004), and the avoidance of areas with gravel or paved roads compared to two-track roads ($\bar{x}$ = 74%, odds ratio = 0.016). Areas with higher percentages of hiding cover ($\bar{x}$ = 59%, odds ratio = 1.009) also were preferred. Application of these models may assist wildlife managers in identifying areas that could serve as potential winter-use sites.

Blood samples were collected from 21 captured elk and 65 harvested elk from three separate study areas in Boyd, Dawes, and Sioux counties of Nebraska. No titers were present for anaplasmosis, bluetongue, or brucellosis. Detectable antibodies for Leptosira interrogans bratislava (8 of 86, 9%) and L. i. hardjo (7 of 86, 8%) were present in all three study areas. Positive sera results were found for epizootic hemorrhagic disease (2 of 86, 2%) and bovine viral disease (3 of 86, 3%) in Dawes and Sioux counties. The low percentage of exposed elk in our sample and the low antibody titer ratios (1:100 to 1:400) suggest that previous exposure to infectious organisms may have occurred, but none of the three populations have active infections.

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INTRODUCTION TO THESIS

History of Elk in North America

According to fossil records, elk (Cervus elaphus spp.) colonized the Alaskan region of North America by crossing the Bering land bridge approximately 120,000 years ago. Elk spread eastward and southward during the Sangamon Interglacial Period between the Illinoisan and Wisconsin Glacial Periods, which ended about 70,000 years ago (Bryant and Maser 1982). With the recession of the glaciers, suitable habitat became available and elk began to establish themselves in areas of prairie-like tundra in Canada and the grassy plains of the Great Plains region of the United States (Guthrie 1966).

Early Records of Elk in Nebraska

Manitoban elk (C. e. manitobensis) were once fairly common in Nebraska, until emigrating settlers began to exploit the large herds as settlers moved through the area (Bryant and Maser 1982). Wildlife literally fueled the westward expansion of European settlers. The first documented elk sightings in Nebraska were by explorers Lewis and Clark in 1803 (Jones 1962). Jones (1962) reported elk sightings as late as the 1880s, although most of the records are from the 1870s and 1880s, which recount sightings of elk in the northeastern counties of Nebraska with the exception of a few sightings along the Oregon Trail.

Pressures of westward expansion, discovery of gold in the Black Hills in 1867, agricultural encroachment, and uncontrolled market exploitation extirpated elk and bison (Bison bison) from Nebraska by the end of the 1880s (Bryant and Maser 1982). Swenk

(1908), an early mammalogist, reported that elk were extirpated from Nebraska about the same time as the bison, in the late 1880s.

In 1907 there were less than 100,000 elk left in North America. By 1922 the herd declined to approximately 90,000 elk, of which greater than 40% resided in Yellowstone National Park (YNP), Teton National Forest and Canada (Bryant and Maser 1982). Translocation efforts made by the Wyoming Game and Fish from the National Elk Refuge (NER) relocated over 1,200 Rocky Mountain elk (C. e. nelsoni) throughout the state of Wyoming from 1962 to 1967 (Robbins et al. 1982). One elk relocation site was the Rawhide Buttes area near Lusk, Wyoming, which is about 25 km west of the Pine Ridge in Nebraska.

Elk Return to Nebraska

Elk reappeared in the Pine Ridge region of northwestern Nebraska during the late 1960s. Elk emigrated naturally from the Rawhide Buttes of Wyoming to the Pine Ridge region of Nebraska. Moralities of tagged elk support this claim. One marked spike bull was released outside of Lusk, Wyoming in February, 1967 and found north of Hay Springs, Nebraska in August, 1967. A second marked elk, a nine-year-old bull, was released in January, 1968 outside the Rawhide Buttes area and the carcass was recovered south of Harrison, Nebraska in September, 1969 (B. Helms, Wyoming Game and Fish Department, pers. commun.).

Elk Management in the Pine Ridge Region

The reappearance and natural establishment of elk in the Pine Ridge region indicates that Nebraska has adequate habitat to support elk. Elk contribute to the State's biodiversity and economy. Recreational opportunities created by hunting seasons and seasonal viewing provides Nebraska hunters and wildlife enthusiasts with a unique local attraction. Elk-related tourism could enhance and stabilize local economies in the region and hunter interest will provide an infusion of funds for natural resource agencies.

Elk provide a myriad of opportunities as well as new management challenges for wildlife managers in the region. Elk in Nebraska, unlike in the inter-mountain states, spend the majority of their time on privately-owned land. Private land in the Pine Ridge provides the majority of cover and high quality vegetation that elk need to survive. In the past, elk have caused monetary loss and damage to ranchers' haystacks, grain crops, and fences. By allowing elk hunting, landowners could offset these realized losses by charging access or guiding fees for hunting and viewing opportunities on their land. Additionally, landowners that allow access to their land for elk hunting and viewing potentially could disperse herds and keep them from concentrating on cropland or stackyards.

The NGPC and other natural resource agencies in the region must consider the complex dynamics of including landowners, local businesses, and statewide wildlife enthusiasts in the development and ongoing implementation of their elk management plans. Several sensitive issues will affect elk management, such as: rights and responsibilities of public agencies, public purchase of private property, agricultural economies, crop damage, hunter behavior, and trespass laws. If managed properly, however, elk will become an important resource for northwestern Nebraska.

The NGPC started actively managing elk in the Pine Ridge region in 1986. Elk management was initiated by depredation complaints from local landowners in the Bordeaux Creek area. The NPGC implemented two hunting seasons, in the falls of 1986 and 1987. Thirty elk were harvested in the Bordeaux Creek area between the two seasons and elk numbers and related damage were reduced to a tolerable level. In 1994, elk numbers and depredation complaints were on the rise again in the Bordeaux Creek area and landowners reported damage in the Hat Creek and Cottonwood Creek drainages, northwest of Crawford, Nebraska.

In response to landowner complaints, the NGPC held a series of public meetings across Nebraska, including communities in the Pine Ridge, to collect public comments and begin talking about the future of elk. After reviewing the public comments, the NGPC developed an Elk Management Plan (Nebraska Game and Parks Commission 1995) that included the following objectives: (1) determine the status of the elk population and maintain a minimum population of 100 elk, with at least six mature (6 + points) bulls, (2) respond to all depredation complaints, (3) implement prescribed hunting seasons, starting in 1995, (4) monitor the overall health of the elk population and prevent contamination of domestic livestock through the removal or treatment of infected elk, and (5) provide informational and educational materials to the public, that promotes free-ranging elk as a valuable component of our native fauna. Hunting seasons in the region from 1995-1998 have allowed for the harvest of 57 and 38 elk in the Bordeaux Creek and Hat Creek areas, respectively.

Elk Research for the NGPC Elk Management Plan

Little was known about the demographics, distribution, movements, and habitat selection of elk in Nebraska. Research-based information is essential for an ecologically sound Elk Management Plan. Information is needed to determine the distribution and seasonal habitat use of elk in the region. Identification and characterization of seasonal elk-use areas will enable managers to select critical habitats for protection or acquisition and to manipulate sensitive areas to attract or disperse elk. A serologic disease survey would enable wildlife managers to assess herd health status and identify potential risk areas for disease transmission.

Thus, the objectives of this study were to: 1) determine the distribution and seasonal habitat use of elk in the Pine Ridge, 2) evaluate the vegetation and microhabitat use of selected winter elk-use sites, and 3) provide information on herd health and condition.

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CHAPTER 1: LITERATURE REVIEW

Elk Distribution and Seasonal Movements

Definitions and Scope

The knowledge of the area an animal uses to fulfill the requisites of life provides insight into the behavioral ecology of the species and can aid in optimizing wildlife management. The abundance, distribution, and movement, of animals are greatly dependent upon the habitat they occupy.

Krebs (1994) defined three classes of animal movement: migration, emigration or dispersal, and immigration. Movement is when an animal leaves its traditional home range in search of establishing an entirely new, distinct home range. Prior to moving, an animal may leave its home range for a short period of time only to return. This type of movement is defined as a temporary excursion.

Migration is a periodic or seasonal movement away from an established home range but eventual return to the same area (Krebs 1994). Several factors influence migratory behavior including: changes in weather, increased snow depth and decreased ambient temperature; food availability; vegetative structure; and breeding. Emigration or dispersal is movement away from an established home range. The key distinction between emigration and migration is the animal is searching to establish an entirely new, distinct home range. Emigration may occur when juvenile bulls leave their natal range or when marginal habitat exists forcing animals to search for better forage, water, space, or cover to avoid predation or disturbance. Conversely, immigration is movement into an area to establish a new home range.

Local movements are similar to migratory movements in that the animal is searching for optimum habitat. Local movements occur daily, seasonally, or annually and are often regular or predictable. Several factors influence local movements including feeding and bedding behavior, human disturbance, offspring care, breeding behavior, and weather conditions (Rongstad and Tester 1969, Sparrowe and Springer 1970).

Home Range Concepts

A home range is the area in which an animal spends the majority of its time. Burt (1943) defined home range as "that area traversed by an individual in its normal activities of food gathering, mating, and caring for young." Dice (1952) described home range as the area an animal covers in its day-to-day travels. Bouliere (1954) stated that an animal's home range is "the area over which the individual or the family group normally travels in search of food… it is not defended by its occupant against other members of the same species, and several home ranges may overlap without giving rise to conflict." An individual's home range must provide enough resources necessary to fulfill the requisites of life for year round residence.

Home range size can be correlated with the body size of the individual as well as the foraging strategies used (Schoener 1968), and the distribution of food, water, and vegetative cover in the area. Distribution of food and cover are probably the most influential factors that determine local or small-scale movements within an animal's home range (Litvaitis et al. 1994). Generally, an individual will develop a fidelity to an established home range that provides adequate cover and food unless something influences it to move, like an increase in population, yearling dispersal, risk of predation, or marginal habitat.

Home range use is typically disproportionate (Samuel and Garton 1985). Topographic features such as riparian drainages or cropland areas can influence the shape, size, and distance traveled by an animal. Radio-tracking individuals to determine their seasonal or annual home range can identify internal characteristics of the area used. Identifying an animal's centers of activity or core areas (areas most intensively used and considered to be the most important points within a homerange) (Brown and Mandery 1962, Samuel and Garton 1985) assists wildlife managers in recognizing habitat components that provide refuge or dependable food sources. These critical areas are selected for their unique traits that attract the individual or group of individuals to the site.

Knowledge of activity center locations may help wildlife managers identify the reasons for dispersal, timing of migrations, affects of weather or other influences on movement, as well as fidelity to specific wintering and summering areas. For example, dominant bull elk lose valuable fat reserves while fighting, herding, and breeding during and directly following the breeding season. The energy used during the breeding season influences dominant bull elk to find secluded pockets of high-nutrition forage, thus avoiding congregated herds of cow elk that feed in groups, thus increasing the potential risk of exposure by association with culling predators (Geist 1982).

Migratory Elk

In general, Rocky Mountain elk are considered migratory, largely because of the habitat they occupy. They follow retreating snow cover and employ a foraging strategy that is opportunistic (Geist 1982). In contrast, Murie (1951) stated that not much is known about the elk that existed in the eastern part of the United States, but with the uniformity of the terrain, and lack of severe winters, elk probably moved little from summer to winter range.

Elk studied in the inter-mountain west have exhibited a myriad of seasonal movements between their summer and winter ranges, typically to satisfy their nutritional requirements, including migratory and nonmigratory behavior. Seasonal migrations of elk have been documented in Idaho (Dalke et al. 1965), Montana (Brazda 1953, Picton 1960, Knight 1970), Colorado (Boyd 1970), Wyoming (Altman 1952, Anderson 1958, Boyce 1989, Rudd 1982), and Yellowstone National Park (YNP) (Skinner 1925, Murie 1951, Knight 1970, Craighead et al. 1972, Shoesmith 1979).

Migration distance and timing are unique for each herd studied. Most spring migrations, depending on local weather conditions, occurred in late April through June, (Anderson 1958, Picton 1960, Craighead et al. 1972). Elk demonstrate a preference to spring, autumn, and summer ranges over winter ranges (Adams 1982). With the first sign of green up, elk signal an apparent eagerness to leave winter ranges and venture through deep snow for the opportunity to find succulent vegetation and cover at higher elevations. Elk prefer wooded, less crowded areas to congested winter range (Adams 1982).

Conversely, with the onset of winter, elk delay their return to winter range until summer pastures are irrevocably snow-buried. Then bands of elk string along their ancestral routes to lowlands where forage is available (Murie 1951). When snow depths reach 15-25 cm, elk begin to migrate to lower elevations (Anderson 1954). Mature elk move without difficulty in lose snow up to 101 cm deep and up to 76 cm in packed or crusted snow (Gaffney 1941). Greater snow depths cause elk to bunch up and move in single file, different animals alternating to break the trail, moving from one open patch of cover to another (Gaffney 1941).

Autumn migration patterns to winter ranges are variable and occur from September to December. Normally, fall migration does not take place until after the rutting season (Murie 1951). The observed behavior of elk grazing summer range areas until forced to move by harsh weather conditions to winter range has been documented in Colorado, Wyoming, Montana, and Idaho (Anderson 1958, Dalke et al. 1965, Boyd 1970, Knight 1970, Craighead et al. 1972, Compton 1975). The distance traveled to reach wintering areas varies from a few km to more then 100 km. Dalke et al. (1965) reported that elk in Idaho migrated 2.4 km from summer to winter ranges. Knight (1970) observed elk moving more then 48 km and Anderson (1958) further reported elk in north YNP migrating over 129 km over the course of 50 days.

Nonmigratory Elk

Elk are opportunistic animals that follow the law of least effort and should be expected to abandon migratory behavior in favor of exploiting a limited area where food is available (Geist 1982).

Complex interactions exist between resident and migratory elk. Martinka (1969) reported that elk in the Jackson Hole Valley during the summer comprise a significant segment of elk from the National Elk Refuge (NER) winter herd. Nonmigratory bands of elk use the NER year-round as well as ranges within 32 km of the Refuge for summer range. Martinka (1969) reported that in 1962-63 yearling males and to lesser extent yearling females remained in the Jackson Hole Valley (18 per 100 females) and in 1963-64 (36 per 100 females) over winter instead of moving to seasonal range. Furthermore, resident elk populations increased in response to closed hunting areas west of the Snake River. Several migratory elk moving through hunting areas to return to the NER were harvested while conditioned resident elk remained safe in areas closed to hunting (Martinka 1969).

Knight (1970) found that marked elk showed a pattern of migrating from winter to spring range and then to summer range. He also reported that elk stayed on winter range until the summer, and then moved to summer range. Boyd (1970) reported that the majority of elk in the White River plateau area migrated from summer to winter range, but some used the winter range year-round. Shoesmith (1979) reported that the Mirror plateau elk occupied a northwest to southeast winter range area running between Pelican

Valley and Gardiner, Montana. Elk remained on winter range through June and into late August. Up to 80% of the year, winter range was occupied by some portion of the Mirror elk population while others migrated over 29 km to Mammoth-Gardiner-Deckard Flats, regardless of weather (Shoesmith 1979).

Craighead et al. (1972) reported that six distinct elk herds used YNP during the summer months. Five of six herds migrated to lower elevations in the winter months to find suitable habitat. The northern Yellowstone herd is comprised of several bands of elk, many of which are nonmigratory and intermingle with the migrating elk in the Firehole, Gibbon, and Madison River drainages (Craighead et al. 1973). The winter range they occupied had several unforested ridges with south facing slopes that held little snow. Thermal areas located in the Madison River drainage area provided atypical winter habitat, allowing nonmigratory elk year-round access to summer range at an elevation greater than 2,134 m with snow depths exceeding 1.2 m (Craighead et al. 1973).

Millspaugh (1995) reported that nonmigratory elk in the Custer National Park, South Dakota, shifted their winter range use from the northwest to the northeast section of the park. Open areas in the northwest section held less snow and provided more abundant forage. In the summer, elk shifted their ranges away from the southwest section of the park due to the high degree of human disturbance.

Factors Influencing Seasonal Elk Movement

Elk movement is influenced by the plant phenology available, dictated by the quality of forage available (Nelson and Leege 1982). In late autumn and early winter, plants enter a dormancy phase of low protein/high fiber and forage quality reduces to its lowest point of the year (Nelson and Leege 1982). Elk select, and appear nutritionally better suited, for herbaceous vegetated winter range over browse vegetated areas in winter range where snow does not limit their access (Nelson and Leege 1982). Elk usually lose weight during winter (Murie 1951) because of increased energetic costs needed to maintain homeostasis.

The timing of elk movements to winter range is dependant upon the quality of forage available. Garrott et al. (1987) reported that seasonal movements of mule deer (Odocoileus hemionus) to winter range was influenced by photoperiod rather than snow depth. Deer selected irrigated and fertilized hay meadows for highly palatable forage. As decreased temperatures and cessation of irrigation combined to lower forage quality, deer moved to sites providing northerly aspects where vegetation is more abundant due to cooler and moister microclimates (Loveless 1964). Garrott et al. (1987) noted that mule deer movements shifted as snow accumulated and forage availability decreased, resulting in increased energy costs (Parker et al. 1984) and deer dispersing to areas providing southerly aspects.

Ruhl (1984) reported that nonmigratory elk in Michigan selected fertilized food plots in the summer and fall. Brown and Mandery (1962) were temporarily successful in changing elk movements and habitat use patterns by locating fertilized plantings away from crop fields. Irwin and Peek (1983) reported that nonmigratory elk avoided southern exposures in late fall and selected old-growth forests at lower elevations where green forage was available under a dense canopy. They also found that elk selected winter range with dense stands of lodgepole pine (Pinus contorta) for resting and foraging sites where snow free southwest facing slopes in sparse timber.

Spring green-up is first evident on south and west facing slopes where high protein/low fiber vegetation is found. Depending on location, elevation, and habitat type, elk are found foraging on grasses, sedges, and early forbs located where these conditions are present. Irwin and Peek (1983) found elk in the spring selecting succulent, early growing forage found in clear-cuts, grass-shrub communities, or seral brushfields.

Elk gradually follow green up with elevation change. Plant selection is based on phenological stage as elk move higher in elevation, shifting diet preference as they continue to summer range. Once they reach summer range, elk movements shift to north and west facing slopes and they select plants growing in shaded high moisture areas where delayed plant growth occurs. Irwin and Peek (1983) reported that during the summer months elk selected succulent forbs or shrubs in north or east facing clear-cuts interspersed with pole-timber that offered good canopy closure. Marcum and Scott (1985) reported that during warm months in dry years, elk shifted to closed-canopy areas and foraged on preferred moist sites at higher elevations to avoid areas with lignified vegetation that contains less protein. Furthermore, they found forage conditions to be the primary determinant in elk distribution and habitat selection.

VerCauteren and Hygnstrom (1998) examined the home range characteristics of white-tailed deer (Odocoileus virginianus) in response to corn development, harvest, and hunting seasons. Deer use of corn peaked at the tasseling-silking stage in mid to late July. Activity centers for home ranges shifted toward cornfields at this time. After crop harvest, deer home ranges increased in area and shifted to nearby wooded cover, suggesting that deer selected the standing corn for cover as well as for succulent forage.

Disturbance Factors Influencing Movement

Elk distribution and movement vary in response to human activity. Human disturbance factors may be short in duration or seasonal, like harvesting of crops, hunting, non-hunting recreational uses, or interactions with domestic livestock. Other disturbances may be continuous or long lasting, varying in degree or intensity, like mining and exploration, timber management, and road usage.

Rice (1988) reported that the greatest disturbance to elk in the Black Hills was hunting. Elk shifted and avoided forage sites with limited canopy cover and moved to small openings with adjacent, dense escape cover. During the hunting season, topographic features no longer sufficed as cover; only thick stands of ponderosa pine with 100% canopy enclosure were selected. Rice (1988) reported that hunters driving logging roads caused a repeated disturbance to once remote country and only dense escape cover prevented elk from repetitive flight responses.

Black et al. (1976) suggested that elk-logging guidelines include leaving stands of timber up to 24 ha in size to provide security cover. Irwin and Peek (1979) reported that elk in northern Idaho used timbered areas greater than 30 ha, yet when roads were left open during hunting seasons, elk were displaced to areas with even more extensive cover.

Skovlin (1982) reported that elk need adequate areas that provide dense escape cover as an essential part of their home ranges to avoid continuous repetitive flight responses caused by hunting. Without adequate cover, elk expend too much energy and subsequently lose weight endangering their well being as they enter winter.

VerCauteren and Hygnstrom (1998) reported the mean size of white-tailed deer home ranges were not affected by muzzleloader hunting, however hunters flushed deer to parts of their range in which hunting was prohibited. Mushroom hunters, agricultural activities, and muzzleloader hunters flushed non-migratory deer from their home range areas but they usually returned by the next morning. Irwin and Peek (1979) reported elk initially moved at the beginning of hunting season but returned to the area of initial displacement after three to four days.

Edge (1982) found that elk in the Montana Chamberlin Creek elk herd moved more than 2,000 m to avoid hunting pressure and often this flight distance included a topographic barrier between the disturbance and the animal. Secondly, elk used safety zones that were closed to hunting within a mile of human habitation or livestock areas.

Cattle Interactions with Elk

The spatial interaction between elk and domestic livestock is a complex phenomenon. In general, elk play a subordinate role to cattle and several factors seem to influence the negative interaction between the two species. Diet similarity, forage availability, animal distribution patterns, and timing influence herbivore competition (Nelson and Leege 1982). Mackie (1970) found that elk preferred areas that received little, if any, prior use by cattle and moved extensively in response to changes in forage availability and distribution of cattle. Rice (1988) reported that the presence of cattle in the Black Hills was a significant cause of elk movement. Elk either vacated pastures when cattle moved in or used areas within the pasture that were not available to cattle. He attributed elk movement to space competition rather than forage competition.

Contrary to the studies mentioned, Ward (1973) found that elk and cattle can be spatially compatible where there is adequate forage. He reported elk selecting foraging areas within 91 m of cattle on several occasions and the opportunity to avoid cattle in the area was separated by a standard four-strand barbed wire fence that had little influence on elk movement.

Elk and cattle may exploit each other's range, but with proper management the two can co-exist and mutually benefit each other. Cattle grazing through pasture rotation can be used to remove herbaceous woody growth and stimulate new regrowth on elk winter range. Alt et al. (1992) described a pasture rotation system that is timed with elevation and plant structure to maximize forage availability for elk when they return to their traditional winter range. Grover and Thompson (1986) reported that elk selected spring feeding sites that had increased green vegetation due to moderate cattle grazing.

Timber Management and Roads in Response to Elk Movement

Prior to 1960, the impact of timber harvest was assumed to benefit elk by providing more available forage (Edge 1982). Human disturbance from logging, loss of hiding and thermal cover, and increased road travel to access backcountry areas have been cited as possible problems for elk (Lyon 1979).

Edge (1982) reported that elk in Montana avoided active logging areas and established a distance of approximately 2,000 m between them and the timber activity. Once this distance was established, they returned to random movements in the area, probably in search of forage. On weekends, elk returned to logging areas, suggesting a preference to some habitat factor and a high fidelity to their home ranges. Lyon (1979) reported that elk moved back into logged areas, but not until the operation was shut down completely. Furthermore, when elk were displaced by timber activities they moved into the next drainage, effectively placing a topographic barrier between them and the disturbance.

Road development in timbered areas, especially in remote country, has increased in on both private and public lands (Edge 1982). The recent development of roads has directly affected elk by decreasing the available habitat, and indirectly by displacing elk from adjacent areas (Pedersen 1979). Thiessen (1976) reported that elk densities increased following road closures. Ward (1980) reported that elk use significantly decreased within 400 m of open roads. Irwin and Peek (1979) reported that elk used timbered areas greater than 30 ha in size during hunting seasons. When roads were open elk were displaced to larger tracks of timber. Irwin and Peek (1979) reported that when roads were closed, smaller timber stands were used by elk for several days during the hunting season and the larger the area closed (75 km^2), the longer elk stayed in the area, suggesting smaller security areas can be utilized by elk if access roads are closed during hunting seasons.

Edge (1982) reported that elk avoid human activities associated with roads, rather than the road itself, and that elk-use is greatly dependant upon the habitat adjacent to roads and the type of disturbance. Road development within logging areas may decrease the area of habitat available for normal use in established home ranges and could shift elk-use sites to marginal or less desirable habitat.

Lyon (1979) found an inverse relationship between the distance at which elk were displaced and percent overstory canopy cover available. Edge (1982) reported elk did not avoid actual road structures; instead they used remote roads as travel lanes from calving through the rutting season. The elk also had a strong preference for areas with a topographic barrier between them and open roads, regardless of traffic volume.

Home Range Fidelity and Management Implications

Home range fidelity is defined as the overlap in an individual's home range during successive years or seasons (Edge et al. 1985). Several studies have observed individually marked elk returning to the same summer and winter ranges that were selected the year before (Murie 1951, Brazda 1953, Anderson 1958, Picton 1960, Knight 1970, Craighead et al. 1972, Shoesmith 1979, Edge et al. 1985 Van Dyke et al. 1998).

The fidelity behavior expressed by yearling elk is established through the cow's long-term maternal care given during the first year. Elk calves rely on their mother's milk as long as possible and are not dispersed until the following spring prior to the dam giving birth to next year's calf and then again during the rut (Geist 1982). Maternal bonding established during the first year allows the calf to learn traditional routes to and from winter range.

Other research has shown that female red deer calves usually adopt ranges that overlap with those of their mothers (Clutton-Brock et al. 1982). Franklin and Lieb (1979) reported that cow elk aggressively influenced their male offspring to disperse, not their female offspring. Geist (1982) suggested that yearling bulls leave their mother's summer range in search of high quality forage during this period of maximum body growth.

Craighead et al (1973) reported that elk segregate to form discrete groups or herds during the spring through the fall and then again on winter range. These groups are in a constant state of flux with individuals moving between groups (Craighead et al. 1973). Furthermore, patterns of movement directly influence the size as well as the shape of home range and seasonal ranges (Craighead et al. 1972). Shoesmith (1979) studied the mother-calf unit and the assemblage of mother-young units forming a cohesive band, group, or herd in relation to seasonal movements. He observed the only enduring social units of elk consisted of individual adults and female units (an adult female, her calf and possibly yearling offspring). Marked elk were usually found in groups constantly changing in composition and adult females with overlapping ranges were individualistic during migratory movements (Craighead et al. 1973, Shoesmith 1979).

Edge et al. (1986) identified two nonmigratory elk herds that selected different home ranges in the Chamberlain Creek drainage area in Montana. These two distinct herds were found to have low rates of dispersal and inter-herd movement, suggesting fidelity is a learned function associated with the matriarchal social system. Furthermore, individual elk had a high degree of fidelity to their home ranges where there was extensive cover, regardless of human disturbance.

It is imperative that wildlife managers know the internal characteristics of an elk's home range in identifying activity centers, and preferred seasonal use areas. Elk are vulnerable to several types of human disturbances, like cattle grazing, timber harvest, mining and exploration, hunting, and winter recreation. In situations where elk show low dispersal rates or a low degree of interaction between other herds on seasonal range, wildlife managers must consider the implications that can result from little or no gene flow to adjacent populations. Knowing the dynamics and stability of the herd or population, their dispersal rates, and harvest objectives of elk all depend on previous knowledge of home range fidelity (Van Dyke et al. 1998).

Van Dyke et al. (1998) compared the home range fidelity of elk in three populations located in Montana and Wyoming over two time periods, 1979-82 and 1988-91, to assess management recommendations for long-term objectives. They found, in all three populations, that the distribution of elk shifted with changes in their activity centers, home range size, and range boundaries used between the two time periods. One of the three groups used the same traditional areas in their home range as observed ten years before. The other two groups shifted their range use. These elk were radio-tracked during the winter-spring of 1981-82 and before this time period this herd was considered one population. Before there was significant overlap in range use and the interchange of individuals, but shifts in range use and spatial separation caused two distinct groups to form using different core areas, activity centers, and summer ranges, suggesting intraspecific competition. Range fidelity was proportional to the numerical increase of the population. Data combined for all herds studied indicated a positive correlation between increasing population density and the degree of change in range use, suggesting that the function of fidelity to historic range may be density dependent (Van Dyke et al. 1998). Furthermore, the dispersal and migration to new ranges would occur during population growth phases as the population approaches or exceeds the carrying capacity of the range.

Management of elk herds is essential where human disturbance can influence home range use and distribution. Wildlife managers should reevaluate home range use and include this objective in their long-term management planning. Identifying and protecting activity centers, evaluating the interchange of gene flow between populations, and assessing numerical growth and the availability of habitat resources should be included in long-term management objectives.

Habitat Selection Associated with Wintering Sites

Elk habitat selection is a multidimensional concept that involves a myriad of environmental and biological factors that interact and influence the behavior of the individual studied (Edge et al. 1987). Selection of specific habitat for winter range, calving grounds, summer forage sites, and breeding territories are influenced by the time of day, season, and sex and age of the animal (Skovlin 1982). Seasonal use sites are also influenced by extrinsic stimuli, such as: topography, weather, quality and quantity of forage, vegetative cover, and space (Skovlin 1982). Knowledge of elk-use sites provides insight for wildlife managers to make specific recommendations concerning proposed activities to elk habitat (Lyon and Ward 1982).

Elk Behavior

Adaptive strategies used by elk allow individual animals to adjust to their environment. The strategies adopted by a species are a product of its genetic and social inheritance, as well as the individual's learning abilities that are influenced by the constraints and opportunities of their environment (Geist 1982). This ability to adapt is unique for each individual and is expressed as the animal's reproductive fitness. Genetic traits, sensory acuteness, learning capacity, and learned behaviors may all influence the individual's movement patterns (VerCauteren 1993). In addition, elk movements are affected by aptitude to exploit resources, avoid predators, function with parasites and pathogens, and select microclimates (Geist 1982). Individuals may have a high degree of reproductive fitness, but their success is dependant upon their ability to collect and process sufficient nutrients to cover their own energetic requirements and have a sufficient surplus for breeding (Clutton-Brock et al. 1982).

To understand the behavior of elk it is important to know the routine they follow. Daily activity patterns for elk may be segmented into feeding, bedding (which involves resting and ruminating), standing (which sometimes involves nursing), and traveling.

Other activities include grooming and scratching or chewing over accessible parts of the body, which is motivated more by parasites than grooming (Harper et al. 1967). Elk spend approximately 90% of their time feeding or bedded down resting or ruminating, while the remainder of undisturbed time is spent idling near the bedding area (Craighead et al. 1973). Elk usually feed before first light and often they will revisit the same feedground that evening, provided they have not been disturbed (Skovlin 1982).

Clutton-Brock and Albon (1989) reported that Highland Red Deer (C. e. scoticus) spent approximately 10 to 12 hours a day feeding, interspersed with resting and rumination periods. During the winter and summer months they noted less time was spent grazing at night than during the day. This seasonal change in grazing pattern is probably a response to reduce heat loss (Clutton-Brock et al. 1982). Craighead et al. (1973) reported elk movement between feeding and bedding sites to be relatively short in distance, and rarely exceeding a 1.6 km during a 24-hour period. Elk spent more time bedded (46% of the time) during the winter months rather than feeding (54% of the time). Suggesting that bedding serves as a strategy to conserve energy by limiting travel through heavy snow, combating the stress of cold weather, and avoiding the expenditure of energy to search for scarce food.

The daily routine for elk changes with the seasons and the energetic requirements needed for the animal to maintain homeostasis. Appetites, as well as metabolic rates of northern cervids, are based on a feast or famine cycle controlled by the changes in day length (Moen 1978, Garrott et al. 1987) or a hormonal balance (Clutton-Brock and Albon 1989).

Speculation exists whether male cervids reduce or lose their appetite in the fall and winter months as an adaptation to rutting activities or in response to the reduced availability of forage. Clutton-Brock and Albon (1989) reported that the forage intake of castrated stags varied less than for intact males, suggesting that reduced foraging amounts during the breeding and winter seasons are a result of hormonal changes. Bull elk are known to search for concentrated forage sites that provide high quality vegetation before the rut to incorporate an optimum feeding strategy (Caughley and Sinclair 1994) to minimize the time spent feeding and to build up fat reserves needed to subsidize rutting activities.

A bull's energy expenditure increases during the breeding season because of fighting with other bulls and herding of harem cows. Clutton-Brock et al. (1982) and Geist (1982) have found that the expenditure of energy increases as a male's harem increases in size, requiring more energy to defend and herd the group from competitors. After the rutting season, bulls do not associate with cows because their large antlers may identify them by culling predators and they cannot afford to feed on lower quality forage (Geist 1982).

Foraging strategies for elk cows and calves also change with the cyclical energy demands throughout the year. Elk calves are known to nurse 5 to 6 times a day, usually twice in the morning and twice in the afternoon, with periods only lasting 40 to 70 seconds (Harper et al. 1967). Geist (1982) suggested elk calves do not have large amounts of fat reserves built up for the oncoming winter so they must rely on their mothers milk as long as possible and select only the most digestible parts of the forage available. Elk calves also have a smaller body size, which translates to a larger surface-to-mass ratio requiring the need for more nutrients to provide the energy necessary to survive when heat is lost.

Cow elk follow two survival strategies, one associates with foraging behavior and the second deals with predator avoidance. Cow elk find the best available forage in the spring and summer months to meet the requirements of lactation and the oncoming winter. Clutton-Brock et al. (1982) reported that lactating females have different maintenance requirements in May through July compared to the winter months. Energy requirements needed for lactation are higher than required for pregnancy and peaks four to six weeks after parturition (Moen 1978). Cow elk are capable of storing up fat reserves, vitamins, and minerals, which inherently lead to increased body size and lowered metabolism rates (Geist 1982).

Cow elk also have the maternal instinct to protect their calves by implementing antipredator strategies. Young calves are protected through cows having a larger body size to fend off predators and through the formation of groups that allow several individuals to keep watch and project a sense of security in safety in numbers. It is hypothesized that cow elk sacrifice forage quality for security while bulls leave the herd and compromise security for succulent forage (Geist 1982).

Topographic Features

Topographic features affect both the local vegetation and the local habits of elk (Skovlin 1982). Elevation, slope, and aspect are three features characterizing the exposure of the landscape, which directly affect habitat use and elk distribution. Aspect, slope, and elevation determine the amount of moisture runoff, direct sunlight, and the intensity of wind speed in local microclimates.

Elevation affects the growing season as well as plant distribution. Elk in the spring prefer to leave crowed winter range at lower elevations to seek out the new available nutritious forage as snowdrifts recede and forested cover at higher elevations becomes accessible. Snowfall is an important component that reduces the availability of forage, increases energetic costs of locomotion, and influences habitat selection and survival.

Slope is known to affect the behavior patterns of elk by determining the microclimate and plant composition (Skovlin 1982). Julander and Jeffery (1964) conducted a study on mule deer, elk, and cattle relationships on range to determine which habitat features are preferred or not selected for each species. They observed elk selecting areas with upper slopes, middle slopes, and major ridge tops over areas with lower slopes, and lower finger ridges. Furthermore, elk shifted their preference of slope position during the fall. Similar areas were chosen with upper slopes and major ridgetops but there was a distinct shift to locations with lower slopes. Results for deer where similar to elk, however cattle selected areas with lower finger ridges and lower slopes.

Elk use of slopes and slope position varies seasonally and reflects the preference for different aspects based on moisture content, plant composition, and open areas uninhibited by snow depth (Skovlin 1982). Slope position may be chosen as a behavioral response for security rather than for forage. Skovlin (1982) reported that it is easier to approach elk undetected from an upslope position rather than down slope. He attributed this to elk directing most of their attention down slope, suggesting that slope position may play a role in escape cover.

Julander and Jeffery (1964) found the greatest proportion of sites used by deer had slopes of 30-40% or greater. Similar results were found for elk using sites with slopes ranging up to 30%. They observed cattle selecting areas with gentle slopes and preferring sites with slopes averaging 0-10%. Rice (1988) reported that elk in the Black Hills selected forested habitat interspersed with small openings with slopes of 0-15%. Elk use decreased as the percentage of slope increased.

Aspect is another component of exposure that affects elk use and distribution. Seasonal use related to aspect is determined by forage availability, thermal comfort factors, and cover type (Skovlin 1982). South and west facing hillsides provide critical winter range with relatively open forage because of the sun angle, wind direction, and shade pattern during the day.

Loveless (1964) reported that mule deer in Colorado actively fed on winter browse in relation to slope position and aspect in response to air temperature and direct solar radiation. When deer first arrived on winter range they preferred cooler areas, open timber habitats and drainage channels, generally avoiding the warmer exposed sites. As winter progressed and freezing temperatures became routine, the deer choose south- and east-facing slopes with open timbered habitat, west facing slopes with shrub cover, and south facing exposures. Heavily timbered northern exposures were avoided. Deer that used south facing slopes preferred top slopes of hillsides that received the longest period of sunlight. He observed deer actively feeding on browse and moving up hillsides just ahead of the sun's shadow.

Millspaugh (1995) reported that nonmigratory elk in Custer National Park shifted their winter range use from the northwest to the northeast section of the park. Open areas in the northeast section held less snow and provided more abundant forage. Garrott et al. (1987) reported that deer movements in Colorado shifted in midwinter from irrigated fields that earlier provided quality forage to areas with northern aspects that held moisture and delayed the lignified phase in plant growth. As snow accumulated, forage availability decreased on the northern hillsides resulting in increased energy costs (Parker et al. 1984) and deer shifted to southerly aspects. Irwin and Peek (1983) reported that nonmigratory elk selected dense stands of lodge pole pine (Pinus contorta) for resting periods and preferred southwest facing slopes for foraging sites that provided grass-scrub stands in sparse timber. Mackie (1970) found that elk used west and north exposures on upper portions of slopes and he noted that cold winds and snow depths did not appear to influence elk-use of northerly exposures.

The vegetative quality and quantity of habitat is determined by elevation, slope, slope position, and aspect. These factors affect the phenological stages of local grasses, and forbs, as well as the structural and a compositional differences in forested areas. Marcum and Scott (1985) observed elk shift habitat-use patterns to closed canopy areas during warm months and shifted forage strategies to moist sites at higher elevations in dry years in response to lower production and dried-out vegetation. They reported that forage conditions were the primary determinant in elk distribution and habitat selection.

Thermal Cover and Homeostasis

Elk are known to select bedding sites or activity centers for the sites unique characteristics that aid in controlling body temperature and maintaining homeostasis. Sources of heat gain and loss include radiation, conduction, convection, evaporation, and metabolic. Craighead et al. (1973) reported bands of nonmigratory elk in north Yellowstone National Park (YNP) selecting winter bedding sites near atypical thermal areas for their warm, dry ground. These elk also selected lodgepole pine habitat throughout the year. During inclement weather these areas were especially favored as bedding sites. McConnell and Smith (1970) reported the importance of dense stands of young pines that provide essential winter bedding sites for big game by providing a means of conserving energy and combating the stress of cold weather and limited food. They found three times as many deer beds in unthinned thickets of ponderosa pine compared to thinned stands.

A bedded and ruminating elk has a higher critical temperature than an actively feeding animal. Elements like wind velocity and moisture raise an animal's critical temperature causing it to spend more energy to maintain homeostasis, while solar radiation, calm days, and dry weather lowers it (Nelson and Leege 1982). Wildlife managers that know the interrelationships between an animals critical temperature, body size, and influential environmental factors can minimize heat loss by providing habitat that enhances winter thermal cover in proximity to preferred forage sites (Nelson and Leege 1982).

Thermal cover is a feature provided by the local habitat that allows elk to regulate their fixed body temperature against the extremes in ambient temperature (Skovlin 1982). Winter bedding sites are typically selected under forested canopies where long-wave radiation is emitted and can be absorbed. Dense tree stands also provide shelter and protection during inclement weather. Trees with good basal area provide elk with a horizontal barrier against the wind and snow. Canopy sheltered areas act as a vertical barrier that reduces wind speed and precipitation. Both barrier features reduce the amount of precipitation falling directly on the animal, thereby reducing the amount of conductive heat lost (Cook et al. 1998). Thermal cover may also reduce the amount of direct solar radiation and resultant heat absorbed by the animal in the summer.

Canopy cover is not the only thermal barrier used by elk. Topographic features like hills or a small bowl or basin could be used to provide a barrier to act as a windbreak. Clutton-Brock et al. (1982) reported the distribution of red deer was affected not only by the location of food resources but also in response to inclement weather. On windy days, the speed and direction of the wind affected deer distribution as well as available grassland areas were used for shelter during these periods.

Armstrong et al. (1983) reported that white-tailed deer selected separate distinct habitats for thermal protection during the day and night. Night beds were selected under a coniferous tree near the bole, close to low branches and surrounded by several trees offering a dense canopy. These factors combined would conserve energy by minimizing wind flow, radiant heat loss, and thermal spread. These forested areas would provide a type of thermal blanket that would retain warmer air masses near the ground provided by the long wave radiation emitted from the forest canopy (Moen 1968, Beall 1974). Armstrong et al. (1983) reported that deer bed sites were used repeatedly during the winter, and in some cases successive winters suggesting, specific habitat selection.

Winter day beds were reported to have low percentages of conifer composition and overhead cover, combined with a southern and western orientation, which suggests elk-selected these sites to absorb solar radiation directly. Open canopy above day beds provided greater exposure to snow accumulations that acted as a barrier used for windbreaks.

Contradictory to the above studies, Cook et al. (1998) commented that the biological importance of thermal cover depends on the frequency and duration of weather. Previous descriptive studies have produced substandard test results on how thermal cover has influenced the condition of elk and improved the likelihood of their survival and reproductive fitness. Animals select habitat for several reasons (i.e. security), which reduces the importance to assess thermal cover. Management conclusions depend on the assumption that habitats providing thermal cover do in fact provide a bioenergetic benefit. Other factors like hiding cover for security could play a role in habitat selection. For instance, during periods of harsh weather where net energetic gains from feeding are negligible, animals may prefer not to feed in psychologically insecure areas, but rather bed in secure areas.

Results from the Cook et al. (1998) study showed that weather moderating effects of forest cover were either too small, or occurred too infrequently to have a significant effect or benefit in warming the animal to be relevant. Solar radiation provided a direct energy input that helped warm the animal, thereby reducing the amount of food energy or endogenous energy required to maintain thermal homeostasis.

Hiding Cover

An indirect measure of the quality of hiding cover is sight distance. Sight distance is the distance at which a certain percentage of a simulated elk, represented by a cover board, can be seen (Skovlin 1982). Horizontal cover, such as tree basal area, or landscape features like tall grassland, gullies or changes in slope, offer protection and obstruct the line of sight.

One way to measure the sense of security for an individual is through the reaction of an animal as it is approached. Flight distance is the measurement of closeness by which an elk can be approached by potential predators, including human, before it takes to flight (Altmann 1958). Individual flight distance may vary in accordance to the time of year, which changes the threshold of sensitivity due to the animal's reproductive and nutritional status, variations in the type of habitat, and past experiences of the individual or group (Altmann 1958).

Rice (1988) reported that the greatest disturbance to elk in the Black Hills was hunting. During the hunting season, topographic features no longer sufficed as cover, only thick dense stands of ponderosa pine with 100% enclosure were selected. Road access provided repeated disturbance by hunters and only dense escape cover prevented repetitive flight responses. Skovlin (1982) reported that dense escape cover is an essential part of elk home ranges to avoid continuous repetitive flight responses caused by hunting. Without adequate cover, elk expend too much energy and subsequently loose weight endangering their well being as they enter winter.

The Edge Effect

Elk are opportunistic animals that use areas that satisfy more than one need. Vegetation communities that provide a diverse habitat and therefore an increased amount of edge are preferred. Dense, old growth forests provide escape and hiding cover, pockets of open canopy provide for thermal benefits, and burned sites with succession plant communities that create a moziac of grasses, forbs, and mixed species are favored over climatic communities that reduce the amount of community edge (Skovlin 1982).

Rice (1988) reported that elk in the Black Hills use areas cleared by wildfire and prescribed burns for feeding throughout the year. Burned areas receive the benefit of added nitrogen fixation in the soil that produces high-energy herbaceous vegetation. Small openings provide abrupt changes in ecotones, along with the enhanced gradient in moisture caused by soil depth, snow retention, and drying conditions from the shaded tree side of areas with edge (Skovlin 1982). These factors combine to retain the best quantity of forage and diversity of plants available. Rice (1988) reported the level of elk use decreased with increased distance from the forest interface and observed elk rarely venturing more than 90 m from forest edge in the summer, spring and fall. During the winter, however elk were often observed in the middle of open meadows, over 400 m from forested areas.

Health and Condition of Elk

Elk are vulnerable to several different types of ailments, including anomalies, bacterial diseases, ecto- and endo-parasites, fungal diseases, neoplastic diseases, nutritional diseases, rickettsial diseases, toxicologic diseases, trauma, and viral diseases. Intrinsic causes of disease include metabolic and endocrine abnormalities, degeneration of organs from age, some neoplasms, genetic defects, and autoimmunity (Hagan and Bruner 1988). Extrinsic causes of disease include living agents such as bacteria, protozoa, viruses or nonliving agents such as cold, heat, trauma, irradiation, chemical toxins, or deficiencies of vitamins or trace elements (Hagan and Bruner 1988).

When a living agent enters an animal's body and causes a negative disturbance, the adverse effects are known as an infection (Hagan and Bruner 1988). Infections to the host may occur from several different sources including, but not limited to, direct contact, airborne vectors, arthropod vectors, and inanimate objects. Disease transmission is an important component to the overall health assessment of wildlife populations.

Another element of assessment is understanding the way diseases manifest and attack different body systems or organs of the animal. Infections can affect the young differently than the old and vary in virulence ranging from acute death to a chronic disease. Carriers of a disease will not always show signs of being infected, or the signs and symptoms may be mild and overlooked or possibly misdiagnosed. For this reason, disease carriers are more dangerous to wildlife populations than acutely diseased individuals because they potentially shed infectious organisms to future carriers for longer periods of time.

In 1995, the Nebraska Game and Parks Commission (NGPC) adopted an Elk Management Plan that recognized elk as a native fauna of Nebraska (Nebraska Game and Parks Commission 1995). The management plan included the objective of monitoring the overall health and physical condition of elk populations in the state. One objective of my project was to provide the NGPC with base-line serologic data on the following diseases: anaplasmosis, bluetongue (BT), brucellosis, bovine virus diarrhea (BVD), epizootic hemorrhagic disease (EHD), and leptospirosis.

We only addressed the six diseases mentioned because of time and money constraints. It is important to recognize that other diseases and health problems could affect the local elk populations. Tuberculosis (TB), chronic wasting disease (CWD), and bacterial diseases like actinomycosis, and necrotic stomatitis are potential management concerns that was not addressed, but have regional significance.

Brucellosis

Brucellosis is a bacterial agent, which belongs to the genus (Brucella). The genus contains six species, (B. abortus), (B. canis), (B. melitensis), (B. neotomae), (B. ovis), and (B. suis). B. abortus is further classified to contain eight biotypes (biovars) (Nielsen and Duncan 1990).

Brucellosis in wildlife was first diagnosed in YNP, Wyoming in bison (Bison bison) in 1917 when two cows aborted and tested positive to B. abortus (Mohler 1917). Murie observed and tested nine elk for B. abortus on the National Elk Refuge (NER) in 1930 (Thorne et al. 1997). B. abortus was documented in early reports by Creech (1930), Rush (1932), and Tunnicliff and Marsh (1935). The disease originated in cattle and affected wildlife in the YNP area close to the end of the nineteenth century (Thorne and Herriges 1992).

Bison and elk are susceptible to brucellosis as are reindeer and caribou (Rangifer tarandus) (Jessup and Boyce 1996, and Thorne et al. 1978), mule deer and white-tailed deer (Odocoileus hemionus and O. virginianus) (Trainer and Hanson 1960), moose (Alces alces) (Fenstermacher and Olsen 1942, Jellison et al. 1953), and pronghorn antelope (Antilocapra americana) (Thorne et al. 1979). Brucellosis infections have also been reported in axis or chital deer (Axis axis) of India, which are now a common free-ranging exotic in Texas (Nielsen and Duncan 1990).

Transmission can occur by intraspecific or interspecific pathways. Abortion is the presumed intraspecific route of transmission for free-ranging elk (Williams et al. 1997). Typically elk seek seclusion for calving and are meticulous at consuming all signs of the birthing process (Geist 1982). The natural act of an elk licking the fetus and ingesting the fetal membranes or vaginal secretions is the most common form of intraspecific transmission (Jessup and Boyce 1996). B. abortus is also present after abortion or calving in the reticuloendothelial tissue of the udder and may be spread to calves through the nasopharynx and conjunctivae (Hagan and Bruner 1988).

Animals that are chronically infected with brucellosis have inflammation from joint infections and lameness is apparent (Jessup and Boyce 1996). Brucella localizes in the lymph nodes of the animal and spreads throughout the blood stream. The bacterium passes through the uterus to the placenta and eventually to the fetus causing abortions (R. Sahara pers. commun.). In males, the bacteria localize in the testes and cause inflammation (Thorne et al. 1982).

Interspecific vectors can include synanthropic birds such as ravens (Corvus corax), predators like coyotes (Canis latrans) and wolves (C. lupus), and arthropods like ticks (Rementsova 1987). B. abortus infections have also occurred in moose, but they are likely a dead-end host (Thorne et al. 1997). Cattle, bison, and elk are vectors and reservoirs of the disease (Williams et al. 1997).

The economic implications that the disease can have on domestic animals have caused the United States Department of Agriculture (USDA) to maintain a vigorous brucellosis eradication program. The USDA Animal and Plant Health Inspection Service (APHIS) administer this program. A pivotal event that affected wildlife and caused elk and bison to move to the forefront of the eradication program occurred in 1988. Cattle from the Parker Land and Cattle Company were pastured on the fringe of YNP and became infected with brucellosis. Investigation by APHIS could not find a bovine source for the disease and attributed the infection to contact with wildlife, either elk or bison. Owners of the cattle filed a $1.13 million dollar lawsuit against the Wyoming Game and Fish Department for damages, but were denied by all levels of the court (Thorne et al. 1997).

Brucellosis could infect cattle, domestic sheep, and elk from the many elk ranches that are established in the Pine Ridge region of Nebraska. The free-ranging elk herd in northwestern Nebraska is relatively small, and Nebraska still maintains a "brucellosis free" status. If the disease was found in the area, and elk were possibly a reservoir or vector of the disease, the consequences would have a significant impact on the Nebraska livestock industry and repercussions on the local elk population.

Leptospirosis

Leptospirosis is a bacterium agent that has more then 150 strains (serovars) identified worldwide, but only one serotype (L. interrogans) is recognized (Kistner et al. 1982). The bacterium is commonly found in dairy cattle and range cattle, but domestic sheep seem to be resistant to infection (Jessup and Boyce 1996). Wild rodents like rats

(Rattus spp.), or raccoons (Procyon lotor), opossum (Didelphus virginianus), and skunk (Mephitis spp.) are proven reservoirs of the disease (Davis et al. 1981).

Wildlife susceptible to leptospirosis includes pronghorn antelope (Thorne et al. 1982), mule deer, black-tailed deer (Jessup and Boyce 1996), and white-tailed deer (Davidson et al. 1981). The first serological reactors in white-tailed deer for Leptosira pomona were reported in Minnesota (Trainer and Hanson 1960). Red deer (Cervus elaphus) have been naturally infected, and moose have been experimentally infected with leptospirosis (Jessup and Boyce 1996).

Leptospirosis is a disease that can be transmitted between cattle and free-ranging wildlife when on common rangeland or pasture (Adrian and Keiss 1977). Elk may act as a reservoir for the disease and potential carriers, infecting livestock and humans (Kistner et al. 1982). Elk were serologically surveyed for leptospirosis and brucellosis in Colorado from 1967 to 1976. The results from over 4,500 blood samples showed titers present for leptospirosis, but the titer ratios were low enough to consider the animals negative (Adrian and Keiss 1977).

Leptospirosis is transmitted by carriers that shed the organism through their urine onto inanimate objects or into common watering sources. The bacterium can pass through or penetrate mucous membranes of the eyes, nose, and mouth. Abrasion or injury to the skin can also be a site for infection (Kistner et al. 1982). Transmission of leptospirosis has also occurred through venereal contact and placental tissues (Jessup and Boyce 1996). Signs and symptoms of the disease are flu-like, such as diarrhea and fever, jaundice, blood-colored urine, and anemia. Long-term effects include damage to the kidneys and liver, and abortion has been reported (Jessup and Boyce 1996)

Anaplasmosis

Anaplasmosis is a disease of ruminants that is caused by the intraerythrocytic rickettsial agent (Anaplasma) (Kuttler 1984). Anaplasmosis is divided into three species, (A. marginale), (A. ovis), and (A. centrale). Anaplasma simply means without plasma. The parasite consists of chromatic material without a cytoplasm (Hagan and Bruner 1988). A. marginale is the causative agent for infecting cattle while A. ovis affects domestic sheep. A. centrale is a pathogenic agent in host red blood cells and is known to affect cattle similarly to A. marginale (Hagan and Bruner 1988, Kuttler 1984).

Elk have been shown to be naturally susceptible to, and experimentally infected with, A. marginale (Harland et al. 1979). Other wildlife that are susceptible to A. marginale either naturally, or through experimentation, are bighorn sheep (Ovis canadensis canadensis) (Howe et al. 1964), bison (Zaugg 1986), pronghorn antelope (Jacobson et al. 1977), white-tailed deer, black-tailed deer (Howarth et al. 1969), and mule deer (Howe and Hepworth 1965). Wildlife susceptible to A. ovis include elk (Post and Thomas 1961), pronghorn antelope (Zaugg 1987), and white-tailed deer (Kreier and Ristic 1963).

Transmission of anaplasmosis occurs through vector-borne hematophagous arthropods such as ticks and biting flies. Uterine transmission is also possible (Zaugg and Kuttler 1984). Several species are mechanical carriers of the disease while others are biological carriers, too. Ticks, particularly the genus (Dermacentor), have been reported to biologically transmit A. marginale to mule deer and black-tailed deer (Keel et al. 1995). Mechanical carriers of the disease include seven species of horseflies from the genus (Tabanidae) and certain species of mosquitoes from the genus (Culicoidae) (Hagan and Bruner 1988). Natural transmission causes concern that deer could be a reservoir of the disease in areas where cattle are present (Christensen et al. 1960). Elk have been shown to be carriers of A. marginale for up to one year and could potentially act as a reservoir in free-ranging conditions (Kuttler 1984, Jacobson et al. 1977).

Anaplasmosis can be an acute or a chronic disease. Young animals are more resistant to the disease than older animals. Signs and symptoms are flu-like such as diarrhea and fever, jaundice, bloody urine, anemia, and a lowering in body temperature as death approaches (Hagan and Bruner 1988 and Jessup and Boyce 1996). Infected animals urinate frequently and their feces are dark colored, blood stained, and mucus covered (Hagan and Bruner 1988). Anaplasmosis may eventually kill an animal due to limited red blood cell (RBC) pack volume, which consequently reduces the amount of oxygen and increases the expired carbon dioxide through the circulatory system (E. Williams pers. commun.).

Anaplasmosis is economically significant to the cattle industry. A survey of bovine diseases by the American Cattlemen's Association placed anaplasmosis fourth among the top ten diseases surveyed (Peterson et al. 1973). The economic impact due to anaplasmosis in 1977 was 50,000 to 100,000 cattle, or lost revenues exceeding $100 million in weight loss and milk production (McCallon 1976). Anaplasmosis could have a devastating impact on elk and the cattle industry in the Pine Ridge area of western Nebraska.

Bluetongue and Epizootic Hemorrhagic Disease

Hemorrhagic disease is caused by either the bluetongue virus (BT) or the epizootic hemorrhagic disease virus (EHD) (Patton et al. 1994). The causative agent for both BT and EHD is from the genus (Orbivirus). This genus for BT contains 24 serotypes (Gard et al. 1987) of which five exist in North America (Work et al. 1992). Epizootic hemorrhagic disease is composed of seven serotypes, two serotypes occur in North America (Work et al. 1992).

Bluetongue is an important viral disease of domestic sheep and cattle (Goltz 1978). Hemorrhagic disease is considered to be the most important infectious disease affecting white-tailed deer in the United States (Nettles and Stallknecht 1992). Many North American wild ruminants have been serologically tested positive with this disease including elk, bighorn sheep, moose, mule deer, black-tailed deer, white-tailed deer, and pronghorn (Robinson et al. 1967, Trainer and Jochim 1969, Hoff and Trainer 1981, Johnson et al. 1986, Howerth et al. 1988, Thorne et al. 1988). The BT virus has also been experimentally produced in wildlife, including elk (Murray and Trainer 1970, Stott et al. 1982).

Epizootic hemorrhagic disease was first identified in white-tailed deer as the causative agent for killing over 1,000 deer in New Jersey (Shope et al. 1955). Epizootic hemorrhagic disease was later found in white-tailed deer in Michigan (Fay et al. 1956) and white-tailed deer and mule deer in South Dakota (Shope et al. 1960). Other deer losses reported in the Midwest included Missouri (Murphy 1957), Nebraska (Bailey 1957), and North Dakota (Richards et al. 1956).

Epizootic hemorrhagic disease and BT are transmitted by biting midges of the genus (Culicoides spp.). Culicoides variipennis is considered the primary vector of the BT virus for domestic ruminants in most of the United States and is a confirmed vector of the EHD virus (Gibbs et al. 1983). Natural disease outbreaks are limited to the warm months of summer and autumn and usually cease with the first killing frost (Kistner et al. 1982). Cause of death for BT and EHD is due to the loss of vascular integrity of the cells in the body (Karstad et al. 1961, Karstad and Trainer 1967, Howerth et al. 1988). The endothelial cells that line the inside of the blood vessels are damaged and thromboses occur, causing a disseminated intra-vascular coagulation (E. Williams pers. commun.).

Many signs and symptoms of hemorrhagic disease are similar to other diseases. Therefore it is difficult to accurately diagnose BT or EHD during suspected outbreaks. Elk infected with EHD showed mild symptoms, like a slight rise in temperature, but no overt signs of the disease (Hoff and Trainer 1973). Other hemorrhagic disease studies involving white-tailed deer have shown signs of appetite loss, fear of humans, progressive signs of weakness, excessive salivation, labored breathing, and comatose (Trainer 1964). Infected deer with the BT virus have shown signs of blood-stained urine and feces, bloody salivation, and hemorrhage of the mucosa of the orbital and oral region, resulting in a rosy or blue appearance, thus the term "blue tongue" (Trainer 1964).

Bovine Viral Diarrhea

Bovine virus diarrhea (BVD) is a contagious disease that is from the genus Pestvirus. Bovine virus diarrhea is closely related to hog cholera, also known as swine fever, border disease virus of lambs, and lactic dehydrogenase virus (Hagan and Bruner 1988). Bovine virus diarrhea is divided into two clinical strains, cytopathogenic and noncytopathogenic (Hagan and Bruner 1988). The differentiation is based on the virulence of the disease. Noncytopathogenic viral strains are associated with chronic viral infections and immunotolerance (Ames 1986) while acute cytopathogenic infections are associated with severe and life threatening symptoms known as mucosal disease (Hagan and Bruner 1988).

Studies have suggested that cattle can be simultaneously infected with two or more strains of BVD and the effect the virus has on the immune system may allow secondary infections to occur (Ames 1986). Bovine virus diarrhea has been diagnosed in cattle throughout the world. Serologic surveys have estimated a rate of 70 to 80% seroprevalence of BVD in the cattle population of the United States (Ames 1986). A serologic survey done in Nebraska showed, where 100 or more cattle serums were tested for BVD, 73% of the samples were positive (Newberne et al. 1961). The virus is not only pathogenic for cattle, but domestic sheep, goats, and wild ruminants are also susceptible (Ames 1986).

Bovine virus diarrhea has been shown to be seropositive in mule deer (Stauber et al. 1977; Couvillion et al. 1980), white-tailed deer (Kahrs et al. 1964), moose (Thorsen and Henderson 1971; Kocan et al. 1986), caribou (Elazhary et al. 1981), pronghorn antelope (Barrett and Chalmer 1975), and bison (Williams et al. 1993). Animals experimentally infected with BVD include mule deer, white-tailed deer, and antelope (Richards et al. 1956). Red deer were experimentally infected with a bovine strain of BVD, but the disease did not result in clinical infection (McMartin et al. 1977).

Bovine virus diarrhea is more prevalent in late winter and spring. It affects all ages of animals, but the young are more susceptible to the disease (Hagan and Bruner 1988). The virus is perpetuated through two cycles of transmission. One source of BVD is through the persistently infected carriers in the herd that shed the virus through nasal secretions, saliva, blood, feces, and urine contact. Bodily fluids can be horizontally transmitted with virus-laden secretions (Traven et al. 1991). Vertical transmission is also possible through the mother's infected blood to the fetus (E. Williams pers. commun.). Infected cattle could transmit BVD and serve as a source of infection to deer because the virus continues to shed for prolonged periods and can be passed to calves in the herd (Van Campen et al. 1997).

Signs and symptoms for BVD can range from a mild transient disease that the animal recovers from to an acute infection of mucosal disease that kills within days (Brownlie 1990). Approximately 70 to 90% of all cattle that are infected have mild symptoms and recover, while one to 5% suffer from mucosal disease and die (Ames

1986). In chronic cases, BVD damages the epithelial tissue of the gastrointestinal, integumentary, and respiratory systems (Ames 1986). Animals that are seriously affected by the disease have a diphasic temperature reaction to leukopenia, dehydration, reduced milk supply, mucoid and sometimes blood-tinged diarrhea, cessation of rumination, conjunctivitis, bluish discoloration of the muzzle, congestion, and ulceration in the mucous membrane of the oral cavity (Hagan and Bruner 1988). Other signs of illness include depression, anorexia, and in severe cases, abortion (Hagan and Bruner 1988).

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CHAPTER 2:

SEASONAL DISTRIBUTION AND HABITAT USE OF FREE-RANGING ELK IN NORTHWESTERN NEBRASKA

Abstract: We radio-tracked and collected 5,789 locations on twenty-one female elk (Cervus elaphus nelsoni) in the Pine Ridge region of northwest Nebraska, from April 1995 to August 1997. We identified two nonmigratory elk herds, the Bordeaux Creek herd located 8 km east of Chadron and the Hat Creek herd situated 12 km west of Crawford. The herds occupied relatively large annual home ranges (48,398 ha and 44,035 ha, respectively). The Bordeaux Creek elk herd was strongly influenced during winter by the presence of alfalfa on a feedground, winter wheat fields, and nearby forested cover. The winter range of elk in the Hat Creek area was without the influence of a feedground. Cropland was used three times more than expected, considering the availability in both study areas for winter range. Both herds shifted to forested habitat during spring. Calving areas were relatively small (982 ha to 1765 ha) compared to other seasonal use areas. Forested areas were used nearly two times more than they were available (47-51%) on calving ranges in both areas. Elk distribution on summer range was influenced in both herds by the presence of field crops (alfalfa, oats, and millet), suggesting elk shifted foraging strategies according to the phenological stage of crops and range grasses to reduce interspecific competition with cattle. Elk use of agricultural fields in both areas was five times greater than expected, considering the availability of

summer ranges. Breeding areas in the Pine Ridge consisted of a mosaic of open grassland and forested areas.

INTRODUCTION

Elk (Cervus elaphus nelsoni) in the intermountain west have exhibited a myriad of seasonal movements between summer and winter ranges, typically to satisfy nutritional requirements. Seasonal migrations have been documented in Idaho (Dalke et al. 1965), Montana (Brazda 1953, Picton 1960), Washington (Schwartz and Mitchell 1945), Colorado (Boyd 1970), Wyoming (Altman 1952, Anderson 1958, Compton 1975, Rudd 1982, Boyce 1989), and Yellowstone National Park (YNP) (Skinner 1925, Murie 1951, Knight 1970, Craighead et al. 1972, Shoesmith 1979).

Several factors influence herd distribution, the distance or direction of movement, and the timing of movement. Elk movement is influenced by inclement weather, food availability, vegetative structure, human disturbance, and breeding. Migration distance and timing are unique for each herd studied. Dalke et al. (1965) observed elk migrating 2.4 kilometers from summer to winter range while Anderson (1958) reported that elk in the YNP area moved over 129 km between seasonal ranges, taking more than 50 days to complete the migration.

Most spring migrations, depending on local weather conditions, occur in late April through June. Elk demonstrate a preference to spring-autumn and summer ranges that provide wooded habitat and less crowded areas over congested winter range areas (Adams 1982). Conversely, elk will delay their return to winter range until summer pastures are irrevocably buried by snow and bands of elk string along their ancestral routes to lowlands where forage is available (Murie 1951). When snow depths reach 15 – 25 cm, elk begin to bunch up and follow one another single file breaking the trail from one patch of open country to another (Gaffney 1941) to lower elevations (Anderson 1954). Adult elk move through loose snow without difficulty up to 101 cm deep and in packed or crusted snow up to 76 cm (Gaffney 1941).

Multiple bands of elk within herds are reported in several areas as having variation in their movements and seasonal ranges. Martinka (1969) reported that nonmigratory groups of elk within the Jackson Hole Valley used the National Elk Refuge (NER) as their summer range, as well as areas within 32 km of the Refuge. Elk used the White River plateau winter range in Colorado year-round, while other elk migrated to and from winter and summer ranges (Boyd 1970). Craighead et al. (1972) observed nonmigratory elk from the north YNP herd exploiting snow-free thermal areas that provide unique habitat throughout winter while snow depths in surrounding areas were 1.2 m deep. Shoesmith (1979) reported that bands of elk in the Mirror plateau area of YNP remained on winter range through June and into late August.

Elk are opportunistic animals that follow the law of least effort and will abandon migratory behavior in favor of exploiting a limited area that provides adequate habitat for year round residence (Geist 1982). An elk's home range needs to supply enough forage, water, cover, and space to fulfill the requisites of life. Distribution of food and cover are probably the most influential factors that affect local movements within an animal's home range (Litvaitis et al. 1994). Edge et al. (1986) reported that nonmigratory female elk in Montana showed a high degree of fidelity to their home range where there was extensive cover, regardless of human disturbance.

A unique opportunity existed in the northwestern panhandle of Nebraska to study the distribution and seasonal movements of elk in the Pine Ridge area. Elk were extirpated from Nebraska in the 1880s, but reappeared in the Pine Ridge region of Nebraska during the 1960s, presumably emigrating from the Rawhide Butte area in eastern Wyoming. The natural reoccurrence of elk in the state spurred the Nebraska Game and Parks Commission (NGPC) to develop an Elk Management Plan (Nebraska Game and Parks Commission 1995). The Elk Management Plan recognizes elk as a native and valuable component of Nebraska's wildlife heritage, particularly in the Pine Ridge area. No research had been conducted on elk in Nebraska before. The purpose of this study was to determine the annual distribution, seasonal home ranges, movements, and use patterns among the free-ranging female elk in the Pine Ridge area of Nebraska.

STUDY AREA

The Pine Ridge region is a unique timbered area of eroded limestone that extends from Wyoming through the Nebraska panhandle and into South Dakota (Figure 1). In Nebraska, the Pine Ridge extends approximately 160 km and is 1-8 km wide, following an easterly to northeasterly direction stretching through Dawes, Sioux, and Sheridan Counties (Nixon 1967). It contains the largest acreage of ponderosa pine (Pinus ponderosa) forest in the state (384,000 ha) (Tolstead 1947; J. Abegglen, pers. commun.

2000). The White River watershed is located north of the Pine Ridge and to the south is the Niobrara River. Elevations range from 1,033 m to 1,753 m above sea level (Ragon et al. 1977).

Four small communities are located in the Pine Ridge area. Harrison (the only town in Sioux County) is located approximately 48 km east of Lusk, Wyoming and the Rawhide Buttes. Crawford and Chadron are located in Dawes County, and Hay Springs is located in Sheridan County (Figure 1). Chadron has a population of approximately 5,900 people and is the largest community in the area. All three counties are sparsely populated (0-0.28 houses/km^2) and road densities are relatively low (0.09-0.46 roads/km^2), consisting of two state highways and several unpaved county roads.

Most of the elk in the Pine Ridge inhabit two areas: the Bordeaux Creek study area (44,398 ha) is located 10 km east of Chadron and the Hat Creek study area (44,035 ha) is located 20 km west of Crawford (Figure 1). Seventy to 100 elk were found in each study area from 1995 to 1997.

The Pine Ridge is dominated by private land (94%) interspersed with public lands (6%) managed by the United States Forest Service (USFS), Nebraska National Forest (NNF) and the NGPC. The NNF administers approximately 20,235 ha of land while the NGPC manages approximately 10,118 ha. Federal lands include the Soldier Creek Wilderness Area that is restricted to off road use and vehicles. State lands within the Pine Ridge are designated as Wildlife Management Areas (WMA) or state parks. The Gilbert-

Baker WMA is located in the Hat Creek study area while the Metcalf WMA and Chadron State Park are situated in the Bordeaux Creek study area.

The Pine Ridge is dominated by ponderosa pine and chokecherry (Prunus virginiana), interspersed with grassland pastures and cropland areas (Tolstead 1947, J. Abegglen pers. commun. 2000). The Hat Creek area is comprised of 47% ponderosa pine (14% burned in 1989), 50% grassland, and 3% cropland. The Bordeaux Creek area includes 51% ponderosa pine, 46% grassland, and 3% cropland.

Deciduous trees found in riparian areas include green ash (Fraxinus pennsylvanica), American elm (Ulmus americana), cottonwood (Populus deltoides), and boxelder (Acer negundo) (Tolstead 1947, J. Abegglen pers. commun.). Dense populations of snowberry (Symphoricarpos occidentalis) make up the ground layer, along with squawbush (Rhus trilobata), wild rose (Rosa arkansana), and poison ivy (Rhus toxicodendron). Grassland pastures are interspersed with small soapweed (Yucca glauca) and Oregon grape (Berberis aquifolium). Predominant grass species include big bluestem (Andropogon gerardii), little bluestem (Schizachyrium scorparium), and Kentucky bluegrass (Poa pratensis). Areas that are heavily grazed are dominated by annual brome grasses (Bromus japonicus and B. tectorum).

Livestock ranching is the primary agricultural enterprise in the region. Cattle and sheep are moved away from the main ranch operation to summer in forested pastures on the table area of the Pine Ridge from mid-May to mid-June. In early fall, after the weaning of yearlings, cattle are moved out of forested pastures and back to the main operation, on grassland pastures. Typical stocking rates average 0.33 animals/ha (D. Hulls, University of Nebraska, pers. commun.). The leading agricultural crops include winter wheat, alfalfa, and oats.

In response to landowner depredation complaints, the NGPC implemented management strategies in both the Bordeaux and Hat Creek areas. In 1993, the NGPC initiated an elk feedground on private land in the Bordeaux Creek area. The feedground provided second cutting alfalfa during late November through March. The feedground program was discontinued in 1997 because of concerns about disease transmission. Feedgrounds were not established in the Hat Creek area. Since 1995, annual hunting seasons have been used to reduce elk populations in both study units. Annual harvests have ranged from five to 31 elk taken between both herds.

METHODS

Capture and Radio Telemetry

Twenty-one free ranging cow elk were captured in the Bordeaux and Hat Creek areas using helicopter net-gunning (Helicopter Wildlife Management, Salt Lake City, Utah) and alfalfa-baited modified Clover traps (Clover 1956) during March 1995, August 1995, December 1996, and March 1996. Captured animals were equipped with mortality sensing 150-151 MHz radio-collars (Advanced Telemetry Systems, Insanti, Minnesota, USA), and two ear identification tags. Ten elk were equipped with radio collars in the Bordeaux Creek study area and 11 collars were placed in the Hat Creek study area.

We located elk by use of radio telemetry using two pickups, each equipped with a 9-element Yagi directional antenna, (Cushcraft Corp., Keene, New Hampshire) and a Telonics Model TR-2 receiver, (Telonics, Mesa, Arizona). Fixed receiver locations (i.e. road intersections) were recorded on 1:24,000 scale topographic maps. Two to three azimuths were taken at fixed receiver locations to locate collared elk. We used the closest possible receiver locations to each animal and attempted to achieve a 90-degree bearing intersection between receiver locations. We flew a Cessna 172 fixed-wing airplane to find missing elk, or to count and locate groups of elk.

We tested the accuracy our telemetry equipment by suspending three radio-collars 1.5 m above the ground at 10 different locations throughout the Bordeaux Creek area. Two independent observers collected ninety azimuths from 10 different receiver locations. Receiver to transmitter distances averaged 601 m (range 297 m to 1,245 m) and the angular error between 60-degree true and estimated bearings was +/- 3.1 degrees.

Visual observations were recorded during the early morning hours, as elk were leaving feeding areas, or in the early evening hours. Ground tracking was done on foot, or by horseback using a 3-element Yagi antenna or a 2-element H-antenna and a Telonics Model TR-2 receiver. With each visual sighting we recorded the date, time, location, number of animals present (cows, calves, bulls, or unknown), and the number of collared elk present, if any.

We located individual elk at different time periods during the day (0300-0900, 35%), (0901-1500, 31%), (1501-2100, 21%), and (2101-0259, 13%) to ensure an accurate representation of individual home ranges and local movements. Elk were typically located daily, and at least once per week, during each time period from April 1995 to August 1997. Tracking schedule was affected by labor, access to private land at all hours of the day, weather and road conditions, and other duties related to the study. The University of Nebraska Institutional Animal Care and Use Committee (IACUC # 94-09-075) approved all aspects of this project.

Location and Data Analysis

Telemetry data were entered into an Excel spreadsheet (Microsoft, Seattle, Washington) and processed with CALHOME (Kie et al. 1996) to determine individual elk locations. Location data were imported into the Map and Image Processing System (MIPS) (MicroImages, Lincoln, Nebraska) Geographic Information System (GIS) and laid over computerized covertype maps. Covertypes were classified as woodland/forest, grassland, and ag/cropland using a LANDSAT thematic mapper (TM) image.

Home Ranges

We used the harmonic mean method (Dixon and Chapman 1980) to analyze elk home ranges. At least 20 locations ($\bar{x}$ = 39, range 20-55) were used to analyze individual seasonal home ranges. We used the 95% isopleths to delineate the boundary of each home range (White and Garrot 1990). Home range periods were divided into five categories: spring (1 March-14 May), calving (15 May-30 June), summer (1 July-31 August), rut (1 September-31 October), and winter (1 November- 28 February).

RESULTS

We collected 5,789 telemetry locations and 413 visual observations on 21 adult female elk from April 1995 through August 1997. The radio-collared elk, and approximately 120 associated elk, segregated themselves into two geographically distinct herds. We observed no interaction between the two herds. Separate annual herd home ranges were observed in the Bordeaux Creek area (48,398 ha, n = 9) and the Hat Creek area (44,035 ha, n = 9).

Winter Home Ranges

During the winter of 1994-95, elk in the Bordeaux Creek area were observed feeding or bedding on or near the NGPC feedground in the early morning or evening hours and foraging on nearby winter wheat fields. Elk were also observed using well-traveled game trails back into the rough forested hills to the south and east of the feedground area.

During the winters of 1995-96 and 1996-97, radio-collared elk shifted their home ranges from breeding areas located on the table area of the Pine Ridge (Figure 2) to sites within 4.8 km to the southeast of the Bordeaux Creek.

Bordeaux Creek elk shifted to their winter home ranges in late November ($\bar{x}$ = 23 November, n = 9), moving an average distance of 4,952 m toward the feedground and winter wheat fields along State Highway 20. Mean home range sizes during the winter were 1,851 ha (n = 9) in 1995 and 4,184 ha (n = 9) in 1996 (Table 1). Bordeaux Creek elk were located on winter wheat fields or the NGPC feedground three times more than expected, considering the availability of agricultural crops in the study area (B. A. Stillings, unpubl. rept. 1999).

No feedground was present in the Hat Creek study area. The winter home ranges of Hat Creek elk were larger than the Bordeaux Creek elk ($\bar{x}$ = 3,628 ha, n = 9) in 1995 and ($\bar{x}$ = 4,258 ha, n = 9) in 1996 (Table 1). Hat Creek elk selected three separate wintering areas compared to the one general winter area used by all Bordeaux Creek elk (Figure 2).

One of the Hat Creek wintering areas was located in the NNF Soldier Creek Wilderness Area. The second area was approximately 5 km north of the NNF Wilderness Area near Tabletop Road on NNF land. The third wintering area was on privately owned land that crossed the Hat Creek and Cottonwood Creek drainages between Crawford and Harrison, just east of the Gilbert-Baker WMA. The area provided small patches of grassland/pastures, seasonal crops, and pockets of Ponderosa pine.

The covertypes used by the Bordeaux and Hat Creek herds during the winter included forested areas (53%), pasture/grassland (37%), and cropland (10%) areas. Hat Creek elk were located on agricultural crops or stack yards three times more often than expected, considering the availability of agricultural crops in the study area (3%) during both winters of 1995 and 1996 (B. A. Stillings unpub. rept. 1999).

Spring Home Ranges

In the Bordeaux Creek area, spring home ranges overlapped winter use areas, although they shifted to the east, where a higher percentage of forested habitat was available (Figure 3). Spring home ranges averaged 4,165 ha (n = 9) in 1996 and 4,052 ha (n = 9) in 1997 (Table 1). Spring home ranges were proximate to areas with isolated hiding cover, and interspersed grassland pastures with high quality forage. Bordeaux Creek spring ranges were concentrated on one area, with the exception of a smaller spring home range area used by two elk located close to the Metcalf WMA. Bordeaux Creek elk used cropland slightly less than expected, considering the availability of agricultural crops in the study area (3%) (B. A. Stillings unpub. rept. 1999).

Hat Creek elk shifted their seasonal spring ranges to three concentrated areas that overlapped existing winter range areas (Figure 3) and averaged 2,887 ha (n =9) in 1996 and 3,906 ha (n =9) in 1997 (Table 1). One spring range site was situated on privately-owned land that bordered the Gilbert-Baker WMA. The second spring home range crossed the Hat Creek and Cottonwood Creek drainages, and the third was situated on Soldier Creek Wilderness Area. Two of the spring ranges overlapped winter range areas and were located on isolated tracks of privately-owned land, while the third preferred site was situated on Soldier Creek Wilderness Area (Figure 3).

Spring home ranges were proximate to forested habitat in undisturbed canyons with early spring growth. Hat Creek elk used cropland in these areas slightly less than expected, considering the availability of agricultural crops within the herd home range (3%) (B. A. Stillings unpub. rept. 1999). The covertypes used by the Bordeaux and Hat Creek elk herds during the spring included forested areas (72%), pasture/grassland (29%), and cropland (2%).

Calving Home Ranges

Calving areas of the radio-collared elk in the Bordeaux Creek area were located almost entirely in forested habitat (Figure 4). The seasonal herd home range shifted 4 km south into heavily timbered areas and 90% of elk locations were in forested habitat. Calving ranges were less than half the size of spring home ranges for all three years studied ($\bar{x}$ = 2,077 ha, n =9) in 1995, ($\bar{x}$ = 1,765 ha, n =9) in 1996, and ($\bar{x}$ = 1,510 ha, n = 9) in 1997. Elk calving grounds overlapped existing spring home range areas. Calving areas were selected on NNF ground as well as privately owned land. Two calving areas were located on the north side of State Highway 20. These calving sites were on private land located on cattle summer range approximately 5 km away from the landowner's main operation.

Six calving areas were located in the Hat Creek area, each within the previously reported spring herd home range (Figure 4). Again, the Soldier Creek Wilderness Area was selected for calving, as well as the area bordering the east side of the Gilbert-Baker WMA. Average calving home range sizes in the Hat Creek study area were 2,887 ha (n = 9) in 1996 and 3,906 ha (n = 9) in 1997.

Other calving areas in the Hat Creek study area were located in small patches of forested habitat. Habitat used by the Bordeaux and Hat Creek elk herds during calving included forest (90%), pasture/grasslands (9%), and cropland (1%). Bordeaux and Hat Creek elk were located on forested areas almost twice as often as expected, considering the availability of forested habitat in the study area (47-51%) (B. A. Stillings unpub. rept. 1999).

Summer Home Ranges

Summer home ranges for Bordeaux Creek elk shifted south to the table area of the Pine Ridge (Figure 5). Summer home ranges were proximate to forested cover, alfalfa and oat fields, and table areas were located on spurs or outcroppings for elk to bed down and cool off in the breeze. Average summer elk home ranges were 4,408 ha (n = 9) in 1995 and 3,814 ha (n = 9) in 1996.

The Hat Creek summer ranges was dispersed into three distinct areas: the Hat Creek and Cottonwood Creek drainage that has served as past winter, spring, and calving habitat, and two areas to the north of the Soldier Creek Wilderness Area. One of these northern summer ranges is on public land and overlaps with a wintering area (Round Top area). The other is on privately-owned land, interspersed with alfalfa and oat fields (Figure 5).

The covertypes used by the Bordeaux and Hat Creek elk herds during summer included forested areas (77%), pasture/grassland (8%), and cropland (15%). Bordeaux and Hat Creek elk were located on alfalfa or oat fields five times more than expected, considering the availability of agricultural crops (3%) (B. A. Stillings unpub. rept. 1999). Bordeaux Creek elk preferred areas with alfalfa and/or oat fields that were adjacent to or within 500 m of forested cover, and Hat Creek elk selected similar habitat within 1,100 m of forested habitat.

Breeding Home Ranges

Breeding home ranges for elk in the Bordeaux Creek study area were located on the table area of the Pine Ridge. This area has forested canyons interspersed with alfalfa, oats, and grassland pastures. A second breeding home range location was 2.5 km near the Metcalf WMA (Figure 6). The breeding home range area near the Metcalf WMA is adjacent to a sandstone escarpment (Beaver Wall) that is a rugged cliff area with grassland pastures and nearby crops. The Beaver Wall area is entirely on privately-owned land and access and disturbance is limited. The average size of the breeding areas in the Bordeaux Creek area was 4,408 ha (n = 9) in 1995 and 3,815 ha (n = 9) in 1996.

The Hat Creek breeding home ranges were located in three distinct areas. One area was located in the Hat Creek and Cottonwood Creek drainages between Harrison and Crawford. The second breeding home range area was west of the drainage system, and the third home range area encompassed the two summer ranges to the north of the NNF Solider Creek Wilderness Area (Figure 6). The breeding home range north of the NNF wilderness area was proximate to cropland areas and forested habitat. The Hat Creek and Cottonwood Creek drainage area was interspersed with small cropland fields, grassland pasture areas, and large areas of forested cover. The average Hat Creek breeding home ranges in the Hat Creek area were 2,887 ha (n = 9) in 1996 and 3,906 ha (n = 9) in 1997.

Cover types used by the Bordeaux and Hat Creek elk herds during the breeding season included forested cover (68%), pasture/grassland (18%), and cropland areas (14%). Bordeaux and Hat Creek elk were located on agricultural crops almost five times more often than expected, considering the availability of agricultural crops in their home range areas (3%). Elk were located on pasture areas less then half of the time expected, considering the availability of pasture areas (50%) (B. A. Stillings unpub. rept. 1999).

DISCUSSION

The reappearance of elk in the Nebraska Pine Ridge during the 1960s, presumably from eastern Wyoming, suggests that Nebraska still has adequate habitat to support elk. The results of this study show that two non-migratory elk herds are established in northwest Nebraska and have selected the Bordeaux and Hat Creek areas within the region.

Winter Elk Movements

Elk are known to select and appear nutritionally better suited for winter range with predominant herbaceous vegetation rather than woody vegetation in areas where snow does not limit their access (Nelson and Leege 1982). Elk in the Pine Ridge prefer forested habitats, but snow is not a limiting factor and quality forage is accessible.

Elk were hunted in the Pine Ridge area in 1985-86 to reduce the depredation complaints from local landowners in both the Bordeaux and Hat Creek areas. At that time, landowners reported elk in the Bordeaux Creek area foraging on crops located on the table area through summer and late fall and then shifting in winter to sites next to State Highway 20 (Figure 3). Winter areas provided flat ground for landowners to plant winter wheat and store round alfalfa bales in stackyards for feeding cattle on nearby winter range. The general elk wintering and summering areas described by landowners in 1985-86 were the same home ranges used by elk in 1995-1997.

The NGPC established an elk feedground in the Bordeaux Creek area from 1993-1998, which reinforced the fidelity of elk to this winter range site. The feedground and adjacent winter wheat fields have created a "preferred area" (Mackie 1970) for elk, which explains why cropland use on the winter range is three times greater than the availability.

We located elk in the same bedding sites on privately owned land within 4.8 km to the south and east of the feedground area during the winters of 1995 and 1996. The fidelity shown by elk to the established wintering area is a response to the quality forage available on the feedground, nearby winter wheat, and accessible forested cover. Also, bedding and loafing areas were nearby in the forested hills between the feedground and winter wheat fields. My results concur with those of Edge (1982); secluded forested habitat provides a buffered area with little human disturbance, thus reducing energetic costs to maintain homeostasis.

Garrott et al. (1987) reported that movements of mule deer (Odocoileus hemionus) to winter range were influenced by photoperiod rather then snow depth. They suggested that the seasonal patterns of deer movements were driven and controlled by seasonal changes in energetic needs and by the quantity and quality of available forage. Nonmigratory elk and deer have both been reported to select fertilized hay meadows or food plots (Brown and Mandery 1962, Ruhl 1984, Garrott et al. 1987). Mangers have reduced crop depredation by changing elk-use patterns with these lure crops.

The Bordeaux Creek elk herd reduced their average home range size from 4,408 ha in the fall to 1,821 ha during the winter of 1995 and the herd increased their winter home range size from 3,815 ha to 4,184 ha in 1996. The change in home range size between years could be explained by the mild winter, which resulted in sparse snow cover and more open patches of grassland habitat interspersed in forested areas to be available. Further contributing factors were the hazing of elk by landowners during winter, and the limited amount of alfalfa provided during the second year at the feedground (Lemon, L. NGPC, pers comm.). Millspaugh (1995) reported that nonmigratory elk in Custer National Park shifted their winter range use to open areas that held less snow and provided more abundant forage.

The Hat Creek elk were not influenced by a feedground in their wintering areas. Their winter ranges were very similar in size during both years studied, averaging 3,628 ha and 4,258 ha for the 1995 and 1996 winters, respectively. Home range sizes were larger than the Bordeaux Creek elk, suggesting an increased effort to search for optimal forage. Hat Creek wintering areas included grass pastures that were not grazed the previous summer by cattle or where cattle were removed in August to allow a period of regrowth before the first killing frost.

Hat Creek elk also used cropland or alfalfa bales in stack yards three times more often than expected, considering the availability. Elk used the Soldier Creek Wilderness Area during the winter, which provided large patches of grassland forage available in previously burned areas that received little human disturbance. The other two selected winter range areas in the Hat Creek area were similar to the Bordeaux Creek area that included rough timbered hills, adjacent cropland, and stack yards.

Spring Home Ranges

Elk dispersed from winter range locations that provided secluded forested habitat. Spring green-up was first evident on south and west facing slopes that received direct sunlight. Spring home range sites were secluded grassland areas in forested habitat, suggesting elk were selecting succulent new grasses, sedges, and forbs.

Irwin and Peek (1983) reported that elk on spring ranges selected early growing forage in clear-cuts, grass-shrub communities, and seral brushfields. Elk in the Pine Ridge selected similar areas with young grasses and forbs while staying in proximate forested cover. I flew once every two weeks in the early mornings over both study areas to observe elk. I observed elk foraging on the community edge that provided small openings with secluded grassland areas surrounded by forest habitat

Spring home range sizes for elk in Bordeaux Creek increased (1,821 ha to 4,165 ha) in 1996, suggesting green-up in the hills affected home range use. In 1997, spring home ranges were very similar in size to winter home ranges (4,184 ha to 4,052 ha). The results for the second winter suggest that the lack of snow cover made available patches of succulent grasses, and forbs interspersed in secluded forested habitat, which are preferred to crowed areas.

Spring home ranges for elk in the Hat Creek area were smaller than winter home ranges (2,887 ha in 1996 and 3,906 ha in 1997) suggesting that elk spent more time and needed more space to search for open grassland areas not covered by snow. Spring weather opened snow covered areas allowing more grassland to become available, increasing forage density, and suggesting individual elk did not have to travel as far to find forage (Knight 1970, Craighead et al. 1973).

Calving Home Ranges

Home ranges for pregnant elk in the Bordeaux and Hat Creek areas were smaller than previous spring home ranges (Table 1). Elk reduced their range use and selected forested habitat (90%) nearly twice as often as expected, considering the availability of forested areas in calving home range areas (B. A. Stillings unpub. rept. 1999). Pregnant elk isolated themselves and calved separately from the herd. Craighead et al. (1972) reported that elk left the herd and went off by themselves a few days before calving. Newborn calves are relatively stationary for the first 10 to 21 days of life (Knight 1970).

Eleven calving sites were located on privately owned land in 1996 and eight in 1997. Two cows calved on public ground in 1996 and three in 1997. Both the Gilbert-Baker WMA and the Soldier Creek Wilderness Area were used during the calving seasons and NNF lands were used in the Bordeaux Creek area. Private land, and public land, both play a critical role in providing the necessary habitat for elk to calve. Elk may have selected publicly owned land to calve more than expected because of the absence of logging operations or low stocking rates of cattle in these areas. Cattle were not present on the Gilbert-Baker WMA during the entire study period. Grazing rotations on NNF land in both study areas were incorporated and a strict rest rotation system was used to benefit cattle and wildlife mutually (J. Abegglen, USFS, pers commun.).

Nine logging operations occurred during the study. Timber harvest occurred in the fall in the Bordeaux Creek area and during the spring, summer, and fall months in the Hat Creek area. Prior to 1960, the impact of timber harvest was assumed to benefit elk by providing more available forage (Edge 1982). During the calving season, increased back-road use by logging trucks, the operation of equipment, and loss of hiding cover, could alter elk movements and possibly push elk to marginal habitat away from preferred areas. Edge (1982) reported that elk in Montana responded to logging activities by avoiding the areas and placing a safe distance of approximately 2,000 m between them and the logging disturbance. Lyon (1979) reported that elk moved back into logged areas, but not until the operations shut down completely.

Summer Home Ranges

Elk distribution within summer range areas in the Pine Ridge appeared to be based on the phenological stages of alfalfa, oats, and millet, and the proximity of hiding cover. Cropland fields in the Pine Ridge lie on semi-flat areas located between ponderosa pine canyons and adjacent forested cover, or on secluded patches of open flat ridges close to forested cover. Bordeaux Creek elk preferred areas with alfalfa and/or oat fields that were adjacent to or within 0.5 km of forested cover. Hat Creek elk selected similar habitat within 1.1 km of forested habitat.

In both study areas, elk shifted their seasonal home ranges by late July ($\bar{x}$ = 24 July), to fields with ripening oats, maturing millet, or second cutting alfalfa. In the evening, elk were either located on forested ridges that were adjacent to secluded cropland fields or feeding during crepuscular and nocturnal periods on virtually unlimited forage before returning to bedding sites by dawn. Lactating cows and pre-rut bulls maximized feeding opportunities by visiting forage sites when humans were not present.

Elk in the Pine Ridge seem to have virtually unlimited forage, suggesting they will use an optimal feeding strategy that allows the best forage available (Caughley and Sinclair 1994) to provide the greatest intake of energy, while reducing or minimizing energy costs (Geist 1982). VerCauteren and Hygnstrom (1998) examined the home range characteristics of white-tailed deer (Odocoileus virginianus) in response to corn development and found deer home range centers and use patterns shifted to corn fields at the peak of the tasseling-silking stage in mid to late July, when the nutrition level was highest.

Elk in the Pine Ridge are following the law of least effort (Geist 1982). They maximize the resources available for reproduction, which inherently would increase their fitness. This law predicts that with increased forage density, less roaming is necessary, and thus summer ranges are smaller than spring home ranges (Knight 1970, Craighead et al. 1973). Strategies followed by elk in the Pine Ridge explain why agricultural crops are used on average five times more often than expected, considering the availability.

Elk also shifted their summer home ranges to avoid cattle. During summer, cattle grazed on forested pastures that were fenced off from cropland areas. As grasses matured and lost protein content, elk shifted to areas that were unavailable to cattle. Cattle may additionally try to avoid interspecific competition with cattle in forested areas. Mackie (1970) found that elk preferred areas that received little, if any, prior use by cattle and move extensively in response to changes in forage availability and distribution of cattle. Rice (1988) reported that the presence of cattle in the Black Hills was a significant factor that affected movements of elk. Elk either vacated pastures when cattle moved in or used areas within pastures that were not available to cattle. Since elk play a subordinate role to cattle, Rice attributed the movement to space competition rather than forage competition.

Breeding Home Ranges

Elk selected forested habitat more than expected, considering the availability during the breeding season. Pastured areas were used less and crops were selected three times more than expected, considering the availability in each study site. Elk established home ranges in areas that provided the highest quality forage for maximum growth potential and to build fat reserves for the upcoming winter.

Elk distribution and movements varied in response to human activity. Deer hunting in the Pine Ridge is a fall tradition and elk hunting was reintroduced in 1985-86 to reduce elk populations and limit depredation. Since 1995, hunters in both study units have perused elk. Elk hunting begins in late September and runs through late October. Firearm season for deer takes place during the second week of November and the Pine

Ridge is a favorite area for Nebraskans to draw a tag. Human disturbance by hunting density in the fall is also affected by turkey hunters, muzzleloader seasons, and archery season.

Rice (1988) reported that the greatest disturbance to elk in the Black Hills was hunting. During the hunting season, elk avoided forage sites with limited canopy and only used areas with small openings adjacent to dense cover. Topographic features no longer sufficed as cover; only thick stands of timber with 100% canopy cover were used. VerCauteren and Hygnstrom (1998) found that the mean size of home ranges for white-tailed deer was not affected by muzzleloader hunting, however hunters did flush deer to parts of their home range in which hunting was prohibited.

Elk in Montana moved more than 2 km to avoid hunting pressure, putting a topographic barrier between them and the disturbance and using safety zones closed to hunting because they were within a mile of human habitation or livestock areas (Edge 1982). Skovlin (1982) reported that dense escape cover is an essential part of elk breeding habitat and that continuous disturbance by hunters in areas where dense cover is not available can cause repetitive flight responses by elk, an over expenditure of energy, and subsequently loss of valuable weight before the upcoming winter. Elk in the Pine Ridge were moved within their home range areas, but they did not disperse to new areas, suggesting that elk may become conditioned and to use areas on privately-owned land that offered dense timber and no hunting.

MANAGEMENT IMPLICATIONS

The Pine Ridge has two distinct nonmigratory elk herds. Elk in both herds showed a strong fidelity to their seasonal areas. The apparent lack of dispersal suggests that elk would be slow to discover and occupy new areas, or ones enhanced by habitat manipulation. Elk in both study areas appear to be attracted to the large quantity of forage and forested habitat offered in the region.

Wildlife managers in the Pine Ridge are still experiencing depredation complaints from landowners in the Bordeaux and Hat Creek areas. The percentage of public land verses privately owned land in the reported annual home range is 6% and 94%, respectively. We recommend involving all interested parties in finding solutions to these issues. It will be important to determine what the most important issues are to landowners, hunters, and other tourists interested in the elk population. We recommend that a survey be conducted to find out the options of landowners, wildlife enthusiasts, and interested hunters in Nebraska elk. Survey questions should address the level of depredation landowners are presently experiencing and what management techniques are needed to address this issue

Wildlife managers should acquire key winter range meadows or fertilized fields through purchase or easements. We recommend these winter range areas be managed for elk, not cattle. Critical winter ranges could reduce depredation by using a pasture rotation system that would allow cattle to rejuvenate grasses and increase forage quality.

Little is known about the elk in the Pine Ridge. Further research is necessary to determine the effects of timber harvest on seasonal areas especially elk calving areas, cattle interaction, and the influence of off-road recreation. Research is necessary to determine the dispersal rates of young bulls within the two populations studied. It is imperative for wildlife managers to know the internal characteristics of the herd range for both sexes studied and the home range boundaries.

We found that elk in the Pine Ridge had a strong fidelity to winter and summering areas. We recommend that wildlife managers continue to monitor population trends between the two study areas. Changes in the stability and fidelity of elk home ranges indicate changes in the population size. Habitat enhancement, and the purchase of privately-owned land will alter elk fitness. Further research is needed to monitor the changes in range use, population trends, and a reevaluation of home range boundaries for setting hunting seasons.

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Table 1. Home range sizes (ha) of elk during spring, calving, summer, breeding, and winter in the Bordeaux and Hat Creek areas, Nebraska, 1995-1997.

Bordeaux Creek

Spring	Calving	Summer	Breeding	Winter
		1995		
No Data	2077	4408	4408	1821
		1996		
4165	1765	3814	3815	4184
		1997		
4052	1510	No Data	No Data	No Data

Hat Creek Area

Spring	Calving	Summer	Breeding	Winter
		1995		
No Data	No Data	No Data	No Data	3628
		1996		
2887	1102	2028	1976	4258
		1997		
3906	982	1574	No Data	No Data

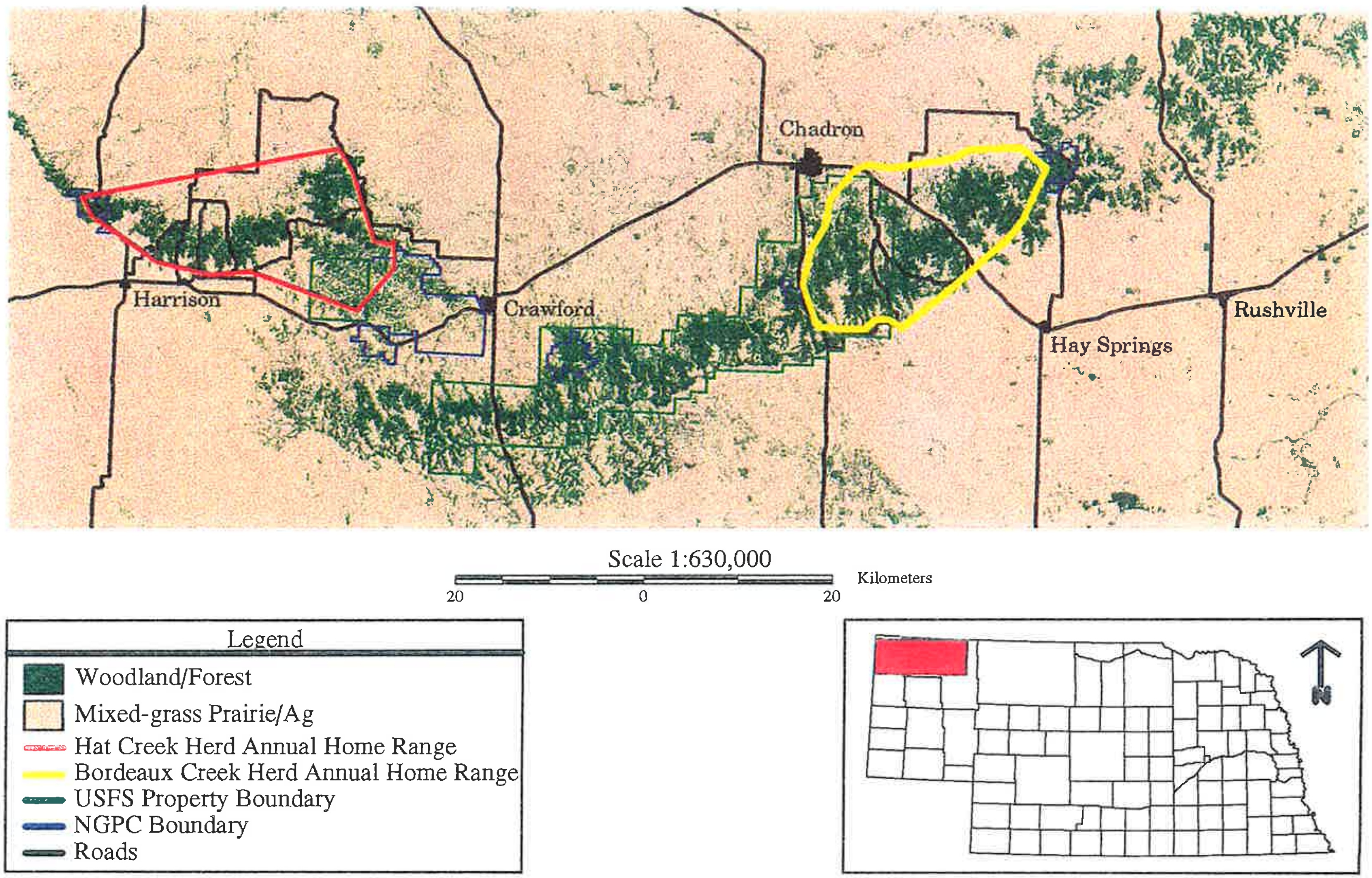

Figure 1. Pine Ridge region of Northwestern Nebraska.

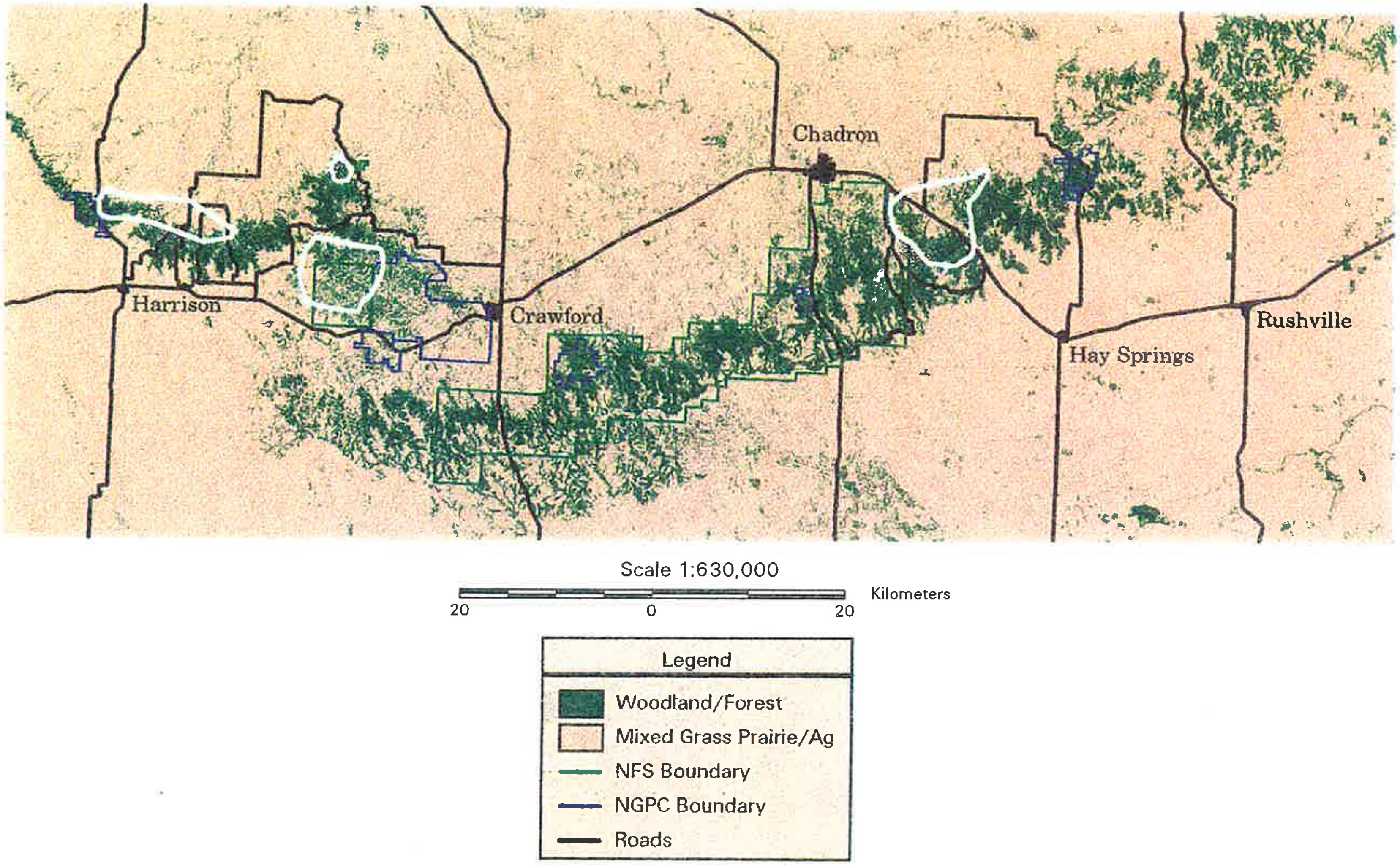

Figure 2. Elk herd home ranges during winter in the Bordeaux and Hat Creek study areas of Nebraska, 1996-1997.

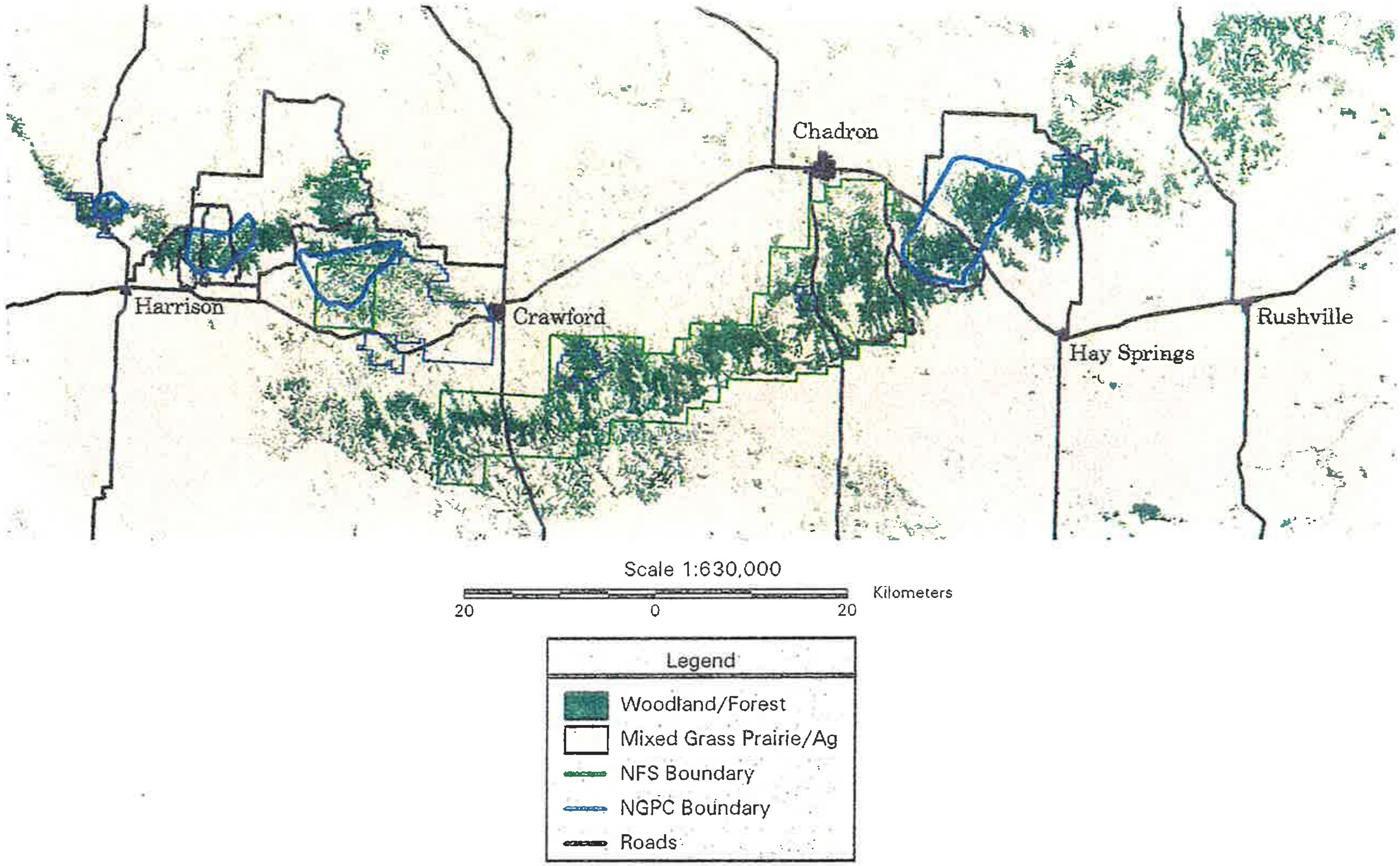

Figure 3. Elk herd home ranges during spring in the Bordeaux and Hat Creek study areas of Nebraska, 1996-1997.

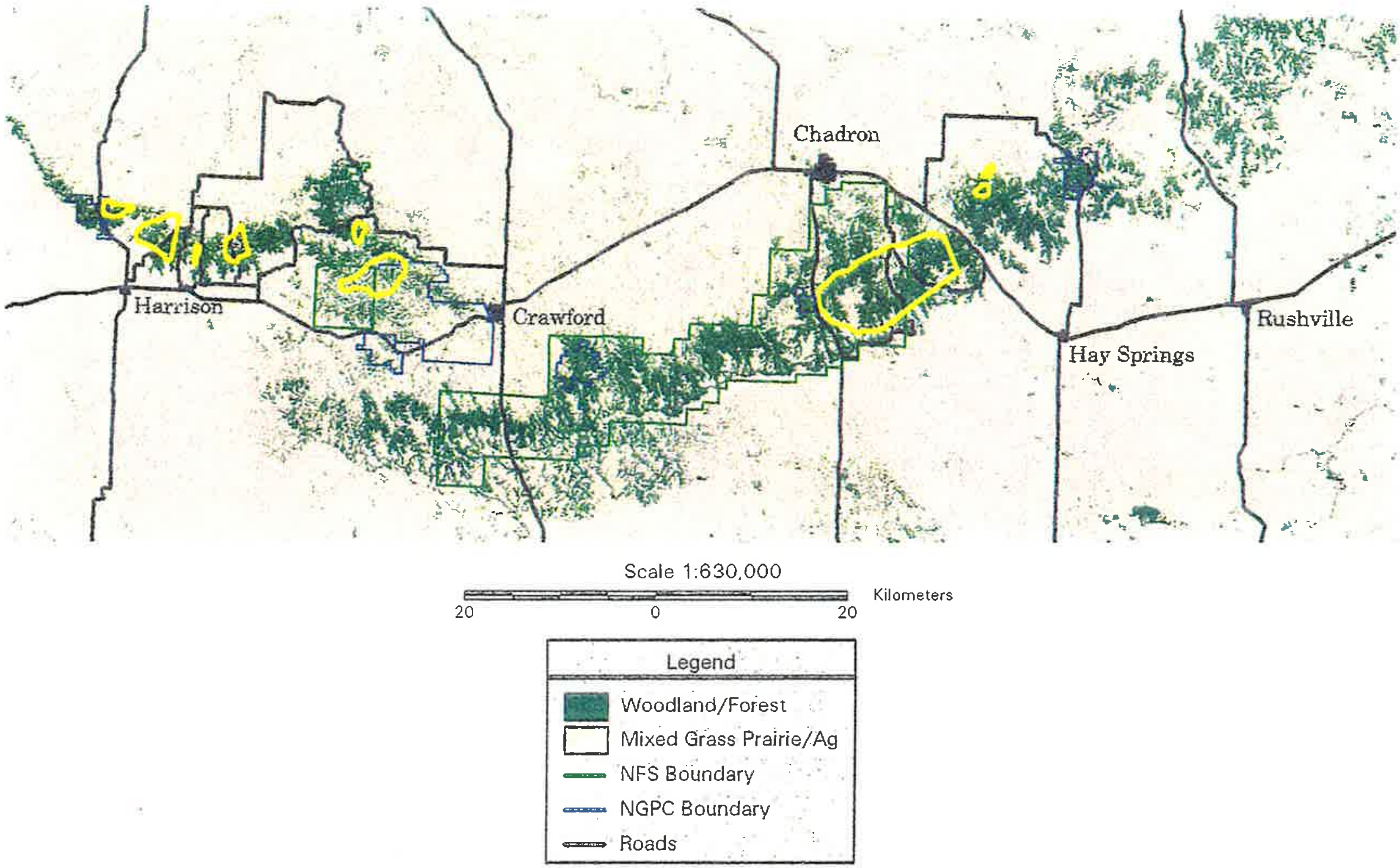

Figure 4. Elk herd home ranges during calving seasons in the Bordeaux and Hat Creek study areas of Nebraska, 1996-1997.

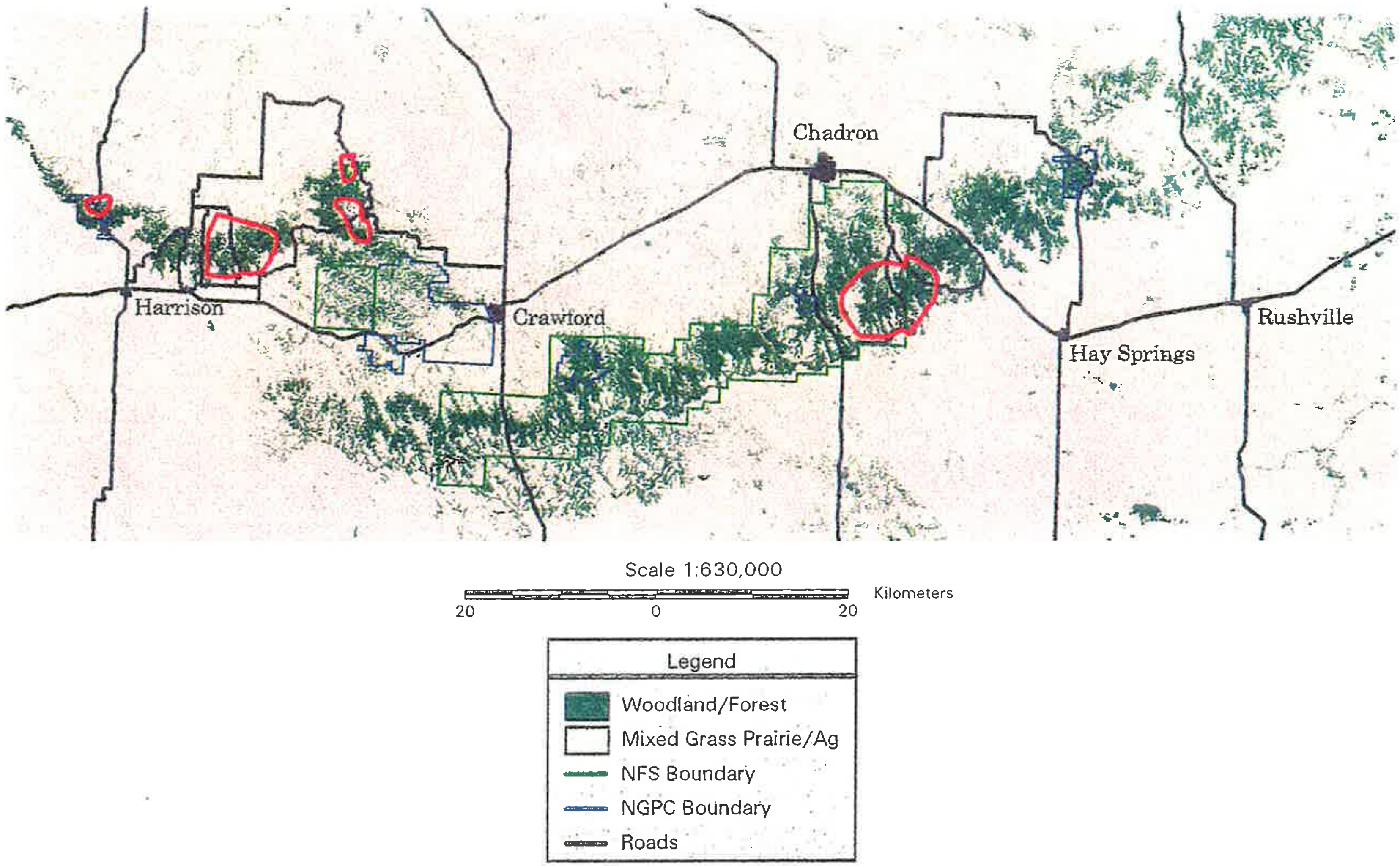

Figure 5. Elk herd home ranges during summer in the Bordeaux and Hat Creek study areas of Nebraska, 1996-1997.

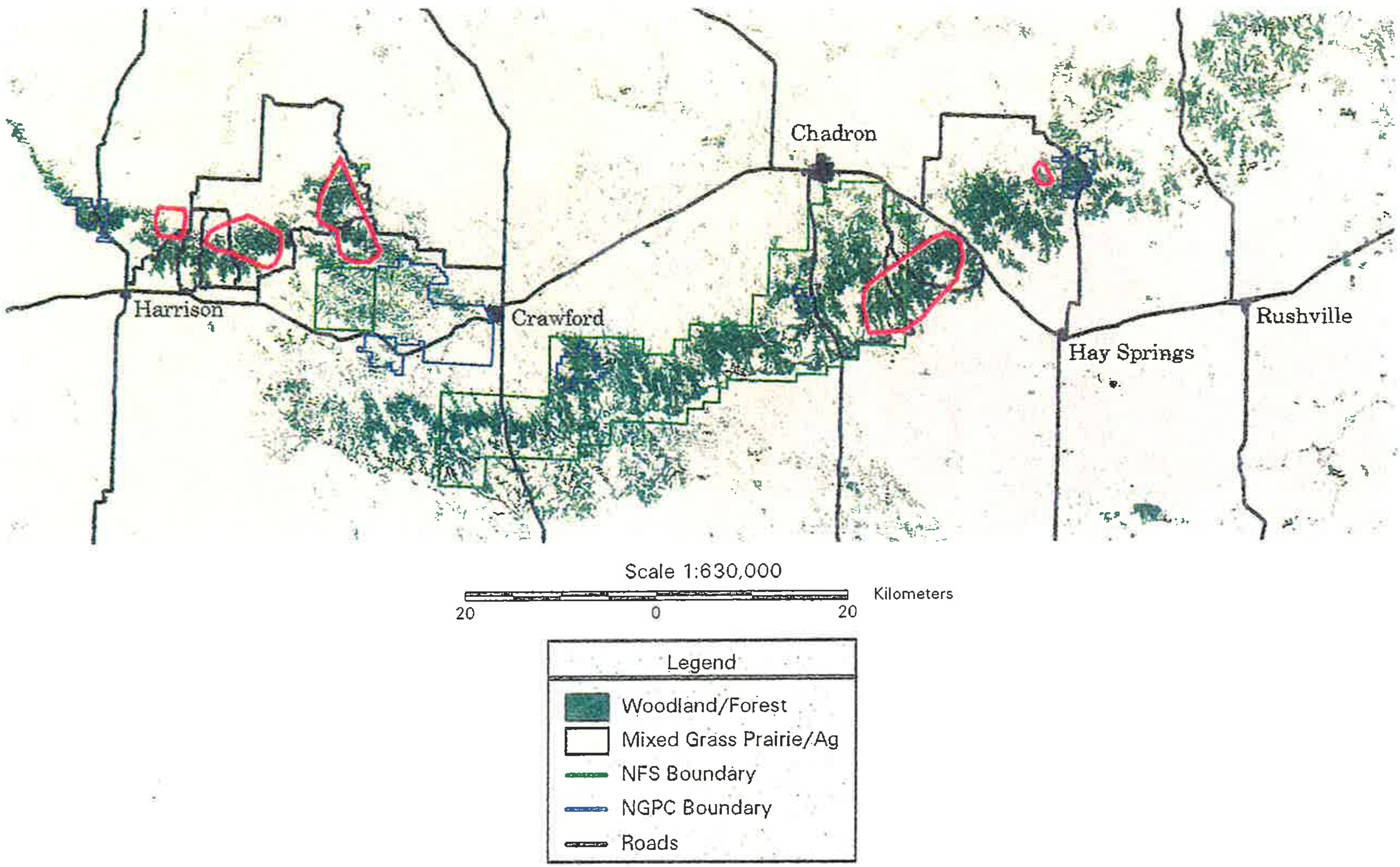

Figure 6. Elk herd home ranges during breeding in the Bordeaux and Hat Creek study areas of Nebraska, 1996-1997.

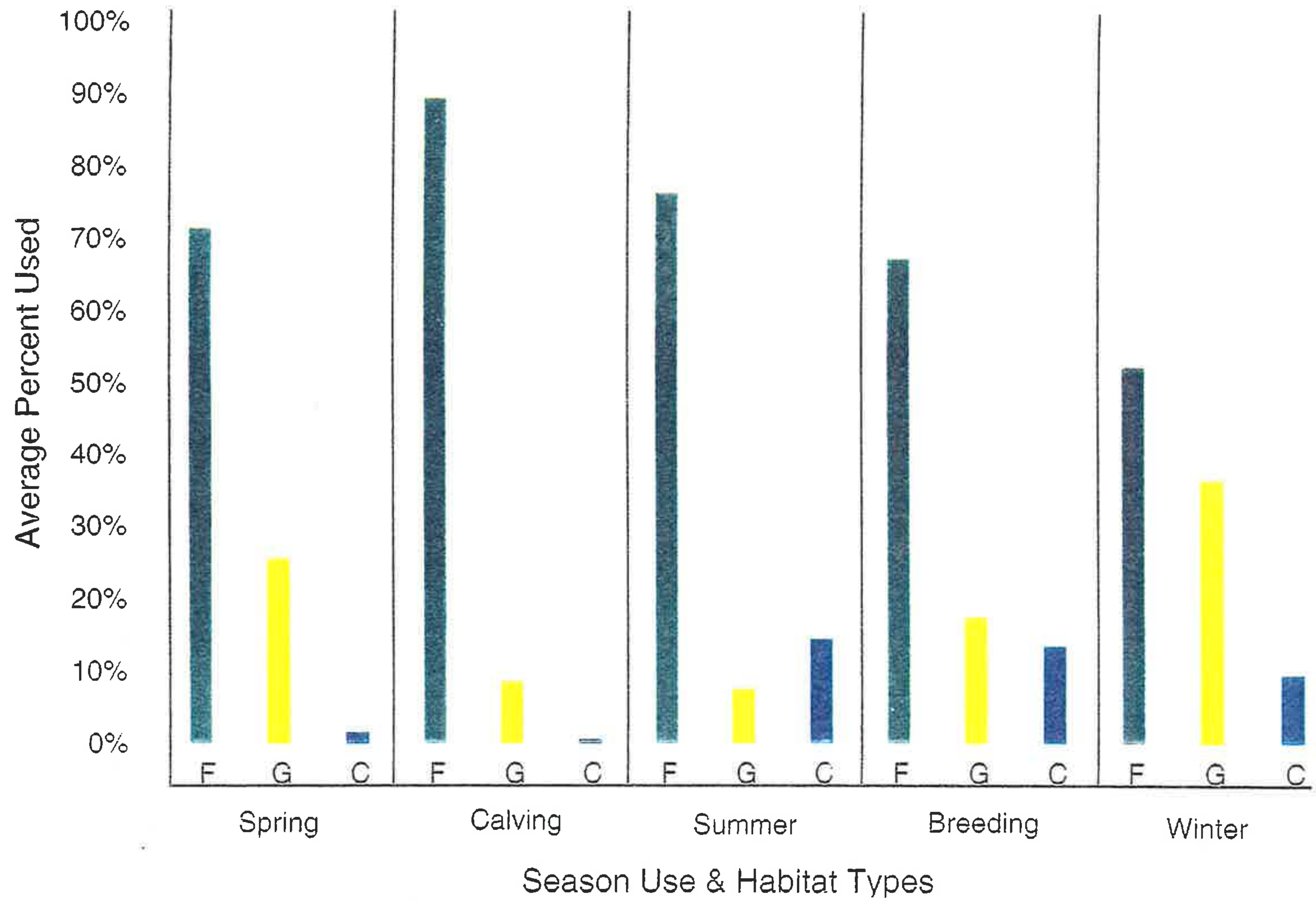

Figure 7. Percent of habitat type used by elk during the spring, calving, summer, and breeding seasons in the Bordeaux and Hat Creek study areas, 1996-1997.

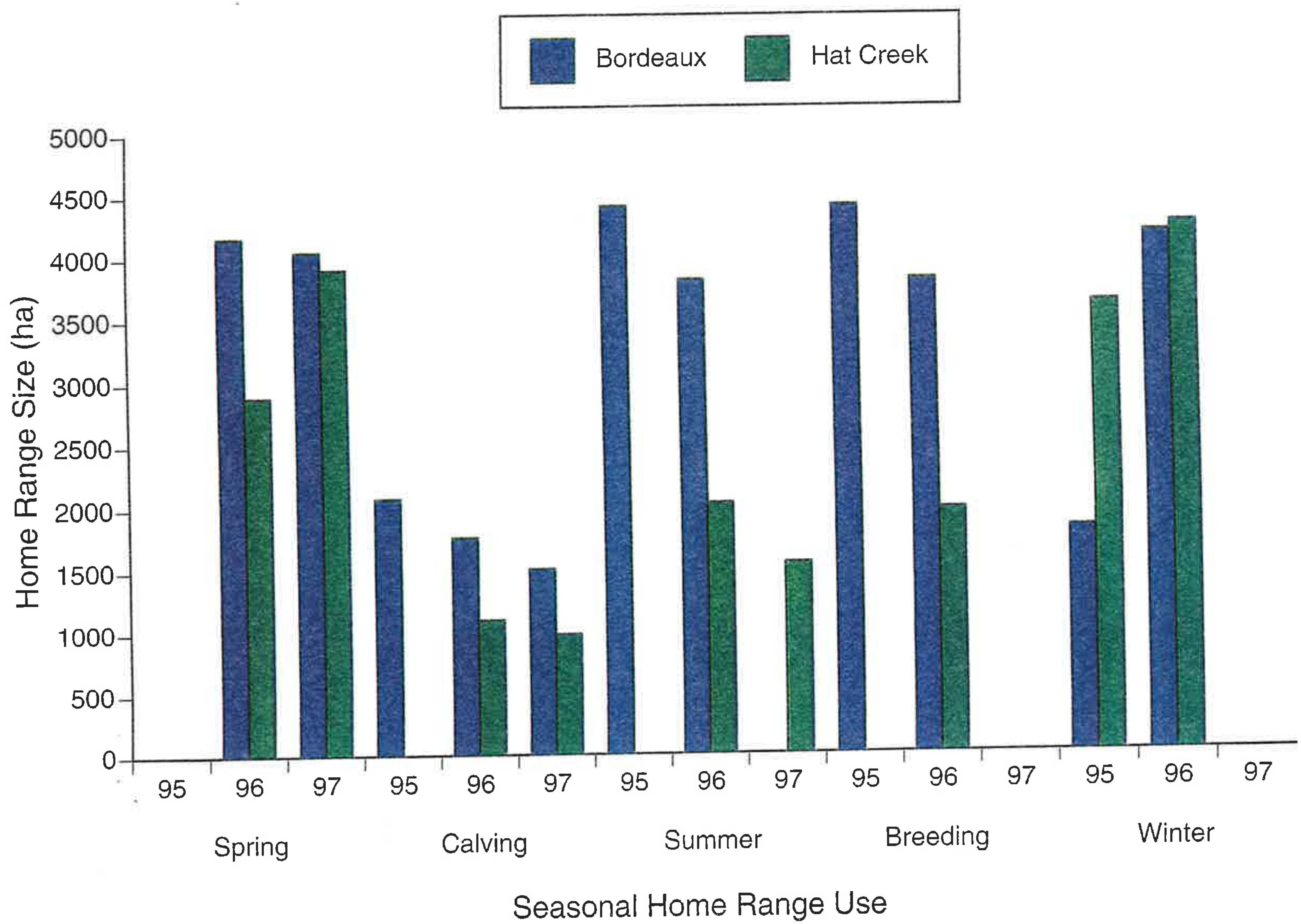

Figure 8. Seasonal home range use used by elk during the spring, calving, summer, and breeding seasons in the Bordeaux and Hat Creek study areas, 1996-1997.

CHAPTER 3:
HABITAT CHARACTERISTICS OF ELK WINTERING SITES IN NORTHWESTERN NEBRASKA

Abstract: We identified 21 elk (Cervus elaphus)-use sites and 44 random sites within the winter home ranges of two non-migratory elk herds in the Pine Ridge region of northwest Nebraska. All 21 elk-use sites were located on private land between January and March of 1996 (n = 13) and 1997 (n = 8). Eighteen habitat variables were measured at each elk-use site and random site. Seventy-two models were generated using the best subsets algorithm and the resource selection function to determine the relative probability of individuals selecting use sites over random locations. The logistic regression model that best described elk habitat selection of winter use sites included the variables: road type, slope, and distance to edge (AIC = 70.7). The second best fitting model included road type, slope, distance to edge, and hiding cover (AIC = 72.5). Odds ratios for both models indicated that elk select core winter use areas that provide an increase in slope ($\bar{x}$ = 16%), distance to edge ($\bar{x}$ = 286 m), and the avoidance of areas with gravel or paved roads compared to logging roads. Areas with higher levels of hiding cover ($\bar{x}$ = 58%) were also preferred. Application of these models may help wildlife managers identify additional habitats that could serve as winter use sites to maintain elk herds during this critical period and to reduce depredation complaints from local landowners.

INTRODUCTION

Elk habitat selection is a multidimensional concept that involves a myriad of environmental and biological factors that interact and influence the behavior of the individuals studied (Edge et al. 1987). Adaptive strategies influence the movements of elk and their selection of habitat use sites, which in turn directly affect the animal's survival and ultimately their reproductive fitness. Selection of core winter areas are affected by the time of day, season of the year, sex and age of the animal, as well as extrinsic stimuli like topography, weather, quality and quantity of forage, vegetative cover, and space (Skovlin 1982).

Elk habitat selection in the intermountain west was well documented (Knight 1970; Mackie 1970; Skovlin 1982; Irwin and Peek 1983; Edge et al. 1987, 1988; Unsworth et al. 1998). Preferred seasonal-use sites however, are unique for each area and population studied (Peek et al. 1982). It is problematic to prescribe site-specific land management practices with the goal of maintaining or enhancing elk habitat without prior knowledge of the local population and their home range use. Wildlife managers are seldom equipped with enough information to make specific site or area recommendations concerning proposed activities in elk habitat (Lyon and Ward 1982). Consequently, the objective of this study was to identify site-specific habitat components selected by wintering elk in the Pine Ridge of northwestern Nebraska.

Elk were extirpated from Nebraska in the 1880s, but reappeared in the Pine Ridge region (Figure 1) during the 1960s, presumably from the Rawhide Buttes area in eastern

Wyoming. The natural reoccurrence of elk in the Bordeaux and Hat Creek areas of the Pine Ridge, along with the increased concern expressed by local landowners regarding crop damage, provided the Nebraska Game and Parks Commission (NGPC) with the impetus to develop an Elk Management Plan for the state (NGPC 1995).

The NGPC Elk Management Plan recognizes elk as a native species and valuable component to Nebraska, particularly in the Pine Ridge area. No research had ever been conducted on elk in Nebraska, particularly on winter habitat selection and home range use.

Habitat used by elk in the Pine Ridge is most likely different than in the intermountain west, because the majority of the land is privately owned and used for raising livestock and agricultural crops. This study will help identify site-specific habitat components that are preferred by elk, assist wildlife managers in recognizing potential elk-use areas on public land, and locate critical wintering areas on private land that could be protected through land acquisitions or easements.

STUDY AREA

The Pine Ridge region is a unique timbered area of eroded limestone that extends from Wyoming through the Nebraska panhandle and into South Dakota (Figure 1). In Nebraska, the Pine Ridge is approximately 160 km long and 1-8 km wide following an easterly to northeasterly direction stretching through Dawes, Sioux, and Sheridan Counties (Nixon 1967). The Pine Ridge contains the largest acreage of ponderosa pine (Pinus ponderosa) forest in the state (384,000 ha) (Tolstead 1947, J. Abegglen pers.

commun. 2000). North of the timbered escarpment lies the White River watershed and to the south is the Niobrara River. Elevations range from 1,033 to 1,753 m above sea level (Ragon et al. 1977).

The Pine Ridge is dominated by ponderosa pine forest, interspersed with grassland pastures, riparian areas, and agricultural fields. Deciduous trees found in riparian areas include green ash (Fraxinus pennsylvanica), American elm (Ulmus americana), cottonwood (Populus deltoides), and boxelder (Acer negundo). In addition, the Pine Ridge has dense populations of snowberry (Symphoricarpos occidentalis), squawbush (Rhus trilobata), wild rose (Rosa arkansana), and poison ivy (Rhus toxicodendron). Predominant grass species include big bluestem (Andropogon gerardii), little bluestem (Schizachyrium scorparium), and Kentucky bluegrass (Poa pratensis). Grassland pastures are interspersed with small soapweed (Yucca glauca) and Oregon grape (Berberis aquifolium) (Tolstead 1947, J. Abegglen pers. commun. 2000).

Two distinct nonmigratory elk herds occupied the Bordeaux Creek study area (44,398 ha), which is located 8 km east of Chadron, Nebraska and the Hat Creek study area (44,035 ha), which is located 20 km west of Crawford, Nebraska. The Bordeaux Creek study area is comprised of 51% ponderosa pine, 46% pasture, and 3% cropland and the Hat Creek study area is made up of 47% ponderosa pine (14% burned in 1989), 50% pasture, and 3% cropland. In both study areas, the percentages of public verses private land are 6% and 94%, respectively. The private land is interspersed with public lands managed by the United States Forest Service (USFS), Nebraska National Forest (NNF) and the NGPC. The NNF administers approximately 20,235 ha of land throughout the Pine Ridge while the NGPC manages approximately 10,118 ha. Wildlife Management Areas (WMA) and state parks provide hunting and recreational opportunities. The Gilbert-Baker WMA is located in the Hat Creek study area while the Metcalf WMA and Chadron State Park are situated in the Bordeaux Creek study area.

Four small communities are located in the Pine Ridge. Chadron is the largest community with a population of approximately 5,900 people. The region is sparsely populated (0-0.28 houses/km^2) and road densities are relatively low (0.09-0.46 roads/km^2), consisting of two state highways and several unpaved county roads. The primary land use is livestock ranching and farming. Landowners run cow/calf or sheep/lamb operations along with raising winter wheat, alfalfa, and oats. Cattle are moved away from the main ranch operation to graze in forested pastures from mid-May to mid-June. In early fall, cattle are moved out of forested areas and back to the ranch head quarters. Typical stocking rates average 0.33 animals/ha (D. Hulls, University of Nebraska, pers. commun.).

Agricultural fields are less than 16 ha and planted in semi-flat patches of open country between forested canyons or on flat areas at the bottom of the Pine Ridge near Nebraska State Highway 20. During our study, nine timber harvests were conducted in the two study areas. In 1996, trees were harvested during the spring, summer, and fall months in the Hat Creek area and only during the fall in the Bordeaux Creek study area.

In 1997, harvest operations occurred during the spring and summer months in the Hat Creek area and there were no active timber operations in the Bordeaux Creek study area.

METHODS

Field Techniques and Data Collection

Capture and Radio Telemetry

Twenty-one female elk were captured and equipped with mortality sensing 150-151 MHz radio-collars (Advanced Telemetry Systems, Insanti, Minnesota, USA), and ear identification tags. Ten collars were placed on elk in the Bordeaux Creek study area and 11 collars were placed in the Hat Creek study area.

The wintering sites of the elk herds were identified by locating individual elk by use of radio telemetry, using two vehicles, each equipped with a 9-element Yagi directional antenna (Cushcraft, Keene, New Hampshire) and a Telonics Model TR-2 receiver (Telonics, Mesa, Arizona). Fixed receiver locations (i.e. road intersections) were marked on U. S. Geological Survey (USGS) 1:24000 scale topographic maps. Two to three azimuths were taken for each elk at fixed receiver locations. We used the closest possible receiver location to each animal and attempted to achieve a 90 bearing intersection. The University of Nebraska Institutional Animal Care and Use Committee (IACUC # 94-09-075) approved all aspects of this project.

Elk-Use Sites

Elk wintering sites were primarily located by radio-telemetry and visual observations. At the end of each tracking day we transferred the collected telemetry data from field notebooks to clear plastic fixed transparencies that overlaid topographic maps. We determined the Universal Transverse Mercator (UTM) coordinate for each elk-use site by using a clear plastic, overlay-type, scale-card (Grubb and Eakle 1988). These coordinates were then entered into a global positioning system (GPS) and ground tracked to the wintering site.

Visual observations of elk were obtained usually in the early morning or evening hours, while driving isolated gravel or private 2-track roads. We used a hand-held 3-element Yagi directional antenna or a 2-element H-antenna with a Telonics Model TR-2 receiver to track collared elk. When elk were observed we searched the approximate location for bedding sites, fresh pellet groups and fresh tracks to confirm the area as an elk-use site. The location of the elk or the fresh sign was marked on a topographic map and used as the center point to evaluate site-specific habitat measurements (Edge et al. 1987).

Winter elk-use sites and random locations were identified from 1 November to February 28. We used the harmonic mean method (Dixon and Chapman 1980) to determine home ranges for individual elk in the Bordeaux and Hat Creek study areas. We combined the 50% isopleth of individual elk to delineate the boundary of each herd home range (White and Garrott 1990).

Randomly Located Winter Sites

Randomly located sites were compared with known winter elk-use sites to determine the significance of selected variables for winter-use areas. Two randomly selected sites were chosen for each known elk-use site to increase sample size. We determined the outermost boundary of the elk-use sampling areas by using the farthest known elk location or home range boundary in each cardinal direction. We used a random number generator available in Excel (Microsoft, Seattle, Washington USA) to select random UTM coordinates contained in this area. Once the random UTM coordinate was chosen we located the site, entered the location into a GPS, and ground tracked to the location.

Center Point Macro-habitat Measurements

The center point of each known winter elk-use site and random location were used to measure site-specific macro-habitat variables. At each center location we recorded the relative aspect of the site and the slope position as top, middle, or bottom slope. We measured the distance to road, water, and nearest edge type in the field or from topographic maps.

Road types were classified as two-track, logging trails, gravel roads, or state highways. Adjacent habitat type was classified as ponderosa pine, deciduous trees, grassland pasture, cropland, or Conservation Reserve Program (CRP) fields. Trees on site were observed and classified as seedling/sapling, pole timber (10-20 cm diameter breast height [DBH]), mature timber (>20 cm DBH), or a mixture of timber classes. Habitat types were classified as ponderosa pine forest, riparian habitat, grassland pasture, agricultural cropland, or burned habitat.

Random Vector Micro-habitat Measurements

Each random location and elk-use site consisted of a center UTM coordinate with eight random radiating vectors marked off at 20 m intervals to obtain a circular plot measuring 31,416 m^2. We measured out two randomly-selected vectors per cardinal direction from each center point using orange survey flags at distances of 20 m, 40 m, 60 m, 80 m, and 100 m. We measured the slope, tree basal area, canopy cover, and hiding cover at each 20-m-sample site along each vector resulting in 40 samples per site. Slope was measured using a clinometer and recorded in degrees. Basal area was measured using a 20-degree prism and recorded as either "counted" (in or border line), or "out" (Higgins et al. 1994). Overstory percent canopy cover was measured in the four cardinal directions using a spherical densiometer (Lemon 1956). Percent hiding cover was measured using a black and white checkered (10 cm^2) density board (2.25 m^2), held at each 20-m sample site with the observer standing at the center location.

Statistical Analysis

Data Manipulation

Mean values were generated for slope, basal area, overstory canopy cover, and hiding cover for each site. Road classifications (indicator variables) were combined into three categories: high-use (gravel and State Highway), logging trails, and two-tracks. The two-track variable was used as the reference category. Edge types were combined into two categories: timbered (ponderosa pine and deciduous which is the reference category) and open habitat (grassland pasture, cropland, and CRP). Timber classifications were combined into three categories, small trees (seedlings and pole timber, which are the reference category), mature trees, and a mixed class.

We used logistic regression (SAS Institute 1990) to compare models with 18 individual habitat components to determine which variables influenced elk selection of winter-use sites. Among the categorical variables mentioned, three categories were combined to avoid problems associated with partial or complete separation (when one or more categories are rarely or never used) (C. Nations pers. commun.).

Variable Selection

Preliminary analyses indicated that six of the 18 measured habitat variables (slope, distance to road, average canopy cover, hiding cover, basal area, and distance to edge) were good candidates for explaining habitat selection of elk-use sites. We constructed a correlation matrix to check for the degree of multicollinearity between paired continuous variables. For pairs with correlation values of $r \geq 0.65$, we selected the variables that were most biologically significant and provided the best direct measure for inclusion in the logistic regression model.

The Pearson correlation test is not meaningful for categorical variables, therefore we checked for potential covariance problems involving adjacent habitat type and road type using *t*-tests, ANOVA, and Chi-Squared tests. First, we tested adjacent habitat type by running two-sample *t*-tests and comparing the means of each of the six continuous variables in the two edge categories mentioned to look for a significant differences ($P < 0.10$), which we interpreted as being highly correlated. Of the six variables mentioned, only slope and distance to road could be entered into a model with edge type, (i.e., $P >$ 0.10 for both variables). The other four continuous variables (canopy cover, hiding cover, basal area, and distance to edge) showed a strong association with edge type and were not entered. Next, we tested the road type against the six possible continuous variables by using an ANOVA to check the equality of means among the three road type classifications. Results showed for all F-tests, the P-value was > 0.10, suggesting a lack of association between the variable road type and each of six continuous variables. Therefore, any of the six variables could be safely entered into a model with road type. Finally, we constructed a 2 x 3 contingency table and ran both the Chi-Squared Test and Fisher's exact Test to assess the level of association between road type and adjacent habitat type. No strong relationship occurred between adjacent habitat type and road type using these tests, suggesting both variables could be entered into the same logistic regression model.

Logistic Regression

We generated 72 models using "the best subset algorithm program," which is built into proc logistic (SAS Institute 1990), to assist in the initial model selection process. The program contains a "resource selection function" which generates the "relative" probability of elk-use sites against randomly selected sites since the absolute probability is unknown (Manly et al. 1993). The resource selection function allows us to compare the mean ratio of elk-use sites against random sites for each model selected to predict the likelihood of elk choosing one site over another.

Selection criteria used for models that best describe winter elk-use sites were based on their ranking from lowest to highest value using the Akaike's Information Criterion (AIC) intercept and covariates values (Burham and Anderson 1992). Individual variables within each model were carefully considered, based on their biological interpretation and odds ratios. In addition, variables were further scrutinized by examining their corresponding confidence limits generated at the 90% level.

We used a logistic regression model to analyze our data because the measured response variable is binary (elk-use or non-use site) and the independent variables were either categorical or continuous. Another viable alternative would be to use a multivariate discriminant analysis program, but this method is sometimes more restrictive (C. Nations, pers. commun.), cannot accommodate categorical variables, and requires multivariate normality (Johnson and Wichern 1998).

Habitat components in each model with paired variables greater than $r \geq 0.65$ were considered, however the final decision to keep or discard a model was not based strictly on significance levels. We selected models with low AIC values, simplicity, and variables of biological importance. We placed a greater emphasis on the multivariate significance once variables reached a threshold ($r \geq 0.65$) versus being concerned with the individual model components. Any model under consideration had to be biologically sound. Therefore, model selection was based on comparatively low AIC values, being relatively simple, and biologically reasonable (Burnham and Anderson 1992).

RESULTS

Distribution of Winter Elk-Use Sites

Two distinct non-migratory elk herds established separate seasonal winter home ranges in the Bordeaux and Hat Creek study areas (Figure 2). During the first winter studied (1994-95), radio collars were not placed in the field, however, local landowners assisted in locating elk-use sites in the Bordeaux Creek area. One elk-use area was located south of State Highway 20 and was reaffirmed by the establishment of a feedground by the NGPC in 1993. Elk were frequently observed feeding and bedded on alfalfa or adjacent winter wheat fields before returning to loafing areas that were located southeast of the feedground area. The second known elk-use area was located north of State Highway 20. The site provided small isolated winter wheat and CRP fields adjacent to a riparian drainage area with forested hills on either side.

The pattern of fidelity previously reported by local landowners was verified by telemetry data during the winters of 1995-96 and 1996-97 (Cover 2000). Elk were located regularly on private land within 4.8 km south and east of the established feedground area and near the winter wheat and CRP fields north of State Highway 20.

No feedground was present in the Hat Creek area. Instead, Hat Creek elk were located on three separate winter range areas (Chapter 2, Figure 3) that provide cattle summer range with good vegetative regrowth, isolated hay meadows with nutritious regrowth, secluded stackyards, burned ponderosa pine grassland, and secluded alfalfa and winter wheat fields.

Models Describing Elk-Use Sites

Realistically, elk most likely are not evaluating each habitat characteristic separately, but rather simultaneously. This would mean that the preference of one habitat component could depend on the presence of another habitat feature.

Elk in the Pine Ridge selected winter-use sites based on the avoidance of human disturbance factors, like high-use roads (state highways and gravel roads) over low-use roads (two-track roads) and favorable environmental factors such as slope, distance to edge, and hiding cover.

Model 1 included the variables: road type, slope, and distance to edge. We chose Model 1 for its simplicity. Only three variables need to be to considered when taking measurements in the field and, Model 1 had the lowest AIC value (70.7) of the 70 models generated. Model 1 is represented by the following equation:

$G(x) = -4.0315 - 4.1616\ (\text{Road 1}) - 0.00376\ (\text{Road 2}) + 0.2026\ (\text{Slope}) + 0.00383\ (\text{Distance to Edge})$

Where $G(x) = \ln [\pi / 1 - \pi)]$ and π is the probability that elk use = 1, which means the probability that a site is used.

We chose Model 2 because it strengthens the argument that the variables road classification, slope, and distance to edge are significant while slightly increasing the AIC value (72.5) as a penalty for adding hiding cover to the equation. Model 2 is represented by the equation:

$G(x) = - 4.2110 - 4.0578\ (\text{Road 1}) - 0.0739\ (\text{Road 2}) + 0.1831\ (\text{Slope}) + 0.00376\ (\text{Distance to Edge}) + 0.00896\ (\text{Hiding Cover})$.

Elk are 4 times more likely to use an elk-use site over a random site (mean value for the Selection Function Ratio = 4.1), given the characteristics measured at each of the sites. Elk in the Pine Ridge select areas that are not proximate to high-use roads (odds ratio for Road 1= 0.016, CI= 0.000 to 0.760). The probability that elk will use a site decreases by 16% for each 1 km that it is closer to a State Highway or gravel road. The 90% confidence levels reported above are relatively narrow, which suggests a high degree of confidence in our interpretation.

Elk also avoided two tracks and logging roads (odds ratio for Road 2 = 0.996, CI = 0.249 to 3.986). The probability of a site being used by elk decreases by 2% as the site is moved 1 km closer to a low-use road. Since the confidence interval lies on both sides of 1.0 our level of confidence is reduced in suggesting that elk avoid low-use roads. We cannot confidently state that elk are selecting or avoiding two-track roads over logging roads because of the low odds ratio. All two-track roads and log trails were located on private land. No logging sites were active near our winter locations when we took measurements, and old logging trails served the same purpose as two-tracks on privately-owned land.

Odds ratio results and 90% confidence intervals for slope (slope =1.225, CI = 1.089 to 1.377) and distance (distance to edge = 1.004, CI = 1.001 to 1.006) are interpreted the same way as above. Since the odds ratio for slope was greater than one, sites were selected for areas providing slope. As the slope of an elk-use site increased by one degree, the probability of that site being used increased by 22%. The 90% lower and upper limits were relatively narrow, suggesting a high level of confidence in our interpretation.

Odds ratio results distance to edge show that sites were preferred with greater distances between the edge and the site. The interpretation is the same, suggesting that as distance to edge increases by 1km, the probability of the elk-use site being used increases by less than 1%. The 90% confidence limits for distance to edge are very narrow, suggesting a high level of confidence in our interpretation.

Model 2 was very similar to Model 1. Again, elk are almost 4 times more likely to use a site over a random site (mean value for the Selection Function Ratio = 3.9), given the habitat variables measured at both sites. The odds ratios confidence intervals and interpretation for Model 2 are almost identical to Model 1 for high-use roads, low-use roads, slope, and distance to edge. The added variable hiding cover was likely a factor in elk habitat selection too, because it has an odds ratio greater than one (1.009, CI = 0.975 to 1.044). Thus, the probability of a site being used would increase by $\leq$ 1% as the percentage of hiding cover increased by 1%. The 90% confidence limits for hiding cover percentages are very narrow, suggesting a high level of confidence in our interpretation.

Characteristics of Winter Elk-Use Sites

All of the known winter elk-use sites selected in the Bordeaux (n = 10) and Hat Creek (n = 11) study areas were located on privately-owned land. We pooled our data across years for elk-use and random locations because of the small sample size that existed when separated between years and between study areas. When we did separate the data, the same common microhabitat variables were included in the models selected. Additionally, all measured elk-use and random sites were situated in the same general home range areas for the entire study.

Elk preferred areas with slopes ranging from 10 to 25% ($\bar{x}$ = 16%, Table 2). Elk preferred areas that provided top or mid-slope positions greater than 90% of the time to in both study areas (Table 1).

Winter elk-use sites were located in areas with forested habitat interspersed with grassland pastures. Eleven (52%) elk-use sites were located in secluded openings of grassland pasture with ponderosa pine trees and surrounding hills positioned to provide protection against the wind and a barrier for hiding cover (Table 2). Nine (43%) of the remaining elk-use sites were located in forested habitat adjacent to small pasture openings used for feeding and open areas for direct solar radiation for thermal regulation (Table 1).

Elk preferred sites that provided relatively open canopy, (Bordeaux $\bar{x}$ = 33%, 12 – 66%, Hat Creek $\bar{x}$ = 34%, 12 – 59%, Table 1). Basal area measurements for elk-use sites averaged 80 m^2/ha (21-281 m^2/ha, Table 2) and trees on site included a mixture of pole-class (52%) and mature ponderosa pine (48%) (Table 1). Roads located closest to elk-use sites were primarily low-use, two-track (76%) or logging roads (19%). The distance from elk-use site centers to roads averaged 1.41 km (0.10 – 2.74 km) (Table 2).

Random Habitat Sites

Sixty-six percent (n = 29) of the random areas measured were located on private land while the remaining 34% (n = 15) were on public land. Average percent slope measured on random sites ($\bar{x}$ = 12, 2- 28%) was less than on elk-use sites (Table 2). Random site center points varied between top (23%), midslope (59%) and bottom slope (18%) positions (Table 2). Trees on site were identified as a mixed timber class (48%), mature (30%), pole-class timber (5%), and grassland areas (18%) (Table 2). The randomly located sites had less canopy cover ($\bar{x}$ = 22%, 0 – 71%) than elk use sites ($\bar{x}$ = 34%, 12 – 66%), and less hiding cover ($\bar{x}$ = 43%, 0- 82%), than elk-use sites ($\bar{x}$ = 58%, 30-83%) (Table 2).

Edge type results for random locations were slightly higher for pine (68%), and cropland (2%) habitat types compared to elk-use sites while grassland pasture was higher for known elk use-sites (Table 2). The mean distance to the nearest edge for random locations (139 km, 0 km to 500 km), was approximately half the distance for elk-use sites. Roads closest to random sites were a combination of low-use type roads, two-track and logging roads (82%), and high-use gravel roads (16%) (Table 2). Roads were also closer to elk-use sites ($\bar{x}$ = 1.08 km).

Adjacent habitats for random locations were slightly higher for pine (68%), and cropland (2%) compared to elk-use sites while grassland pasture was higher for known elk-use sites (Table 2).

DISCUSSION

Distribution of Winter Elk-Use Sites

During the winters of 1995-96 and 1996-97, all 21 elk-use sites in the Bordeaux and Hat Creek study areas were located on privately-owned land. The selection of these sites suggest that elk were strongly influenced by the proximity of high quality forage and forested cover, fidelity to home range, and the low degree of human disturbance. The Bordeaux and Hat Creek elk herds were located on winter wheat fields and the Bordeaux Creek herd used the feedground three times greater than the availability of agricultural crops during both winters studied (Chapter 2). We observed elk feeding before first light and in the evenings when low light and human disturbance was minimal, suggesting individuals may be selecting these times to avoid human activity and for security. However, some days, elk were observed in the Bordeaux Creek area feeding during the day. They used winter wheat fields or the feedground that was adjacent to the State Highway, suggesting that to a degree, elk in the Bordeaux Creek area were conditioned by the available artificial feed source.

Skovlin (1982) reported similar results of elk feeding before first light and often revisiting the same feeding areas that evening, provided they had not been disturbed. Rowland et al. (2000) reported similar results to our study in that elk during the spring and summer, avoided road-related human activities. However, they also observed that the farther elk were from a road-related disturbance; other factors such as amount and quality of forage influenced their movement and distribution. In Custer State Park, South Dakota, wildlife mangers have been thinning forested areas adjacent to roads to increase wildlife viewing opportunities. The open habitat created next to roads has improved forage quality and quantity and has been shown to attract elk when vehicle use is low (J. Millspaugh, unpublished data). Cooper and Millspaugh (1999) suggest that elk bed sites are dependent on proximate forage and that further research is needed to investigate this hypothesis.

Habitat Modeling

We identified two models using logistic regression that can serve as a measure of winter habitat selection for elk-use sites in the Pine Ridge region of northwest Nebraska. Model 1 included the variables: road type, slope, and distance to edge. Model 2 included the variables: road type, slope, distance to edge, and hiding cover. The models indicated that elk avoided high-use roads (State Highways and gravel roads), and preferred sites with increased distance to edge, degree of slope, and percentage of hiding cover. Models such as this enable wildlife managers to make probabilistic predictions of winter habitat use and to prescribe site-specific recommendations (Lyon and Ward 1982).

Wildlife researchers have tried to understand how human activities affect the suitability and selection of habitat components based on their biological importance. In the past, models have been generated to compare animal use of presumably biologically important habitat variables to their availability, and thereby draw inferences about resource preferences (Millspaugh et al. 1998). Model application helps predict the resource selected by the individual, or groups of individuals, and the likelihood of where and when they will forage, rest, and reproduce (Cooper and Millspaugh 1999). Resource selection models generated for wildlife at the global or landscape scale are used for ecosystem management by assessing the cumulative effects that impact the species. For example, Mace et al. (1999) modeled the relative probability of grizzly bears (Ursus arctos) in western Montana using landscape features in the absence and presence of human activity (potential and realized habitat effectiveness) during the spring, summer, and fall.

Our objective was to evaluate habitat selection at the local scale. We compared winter habitat variables measured at winter elk-use sites against randomly located sites in the Pine Ridge to identify the components selected by elk. Application of these models will help wildlife managers identify additional critical wintering areas that could serve to maintain elk herds in the Pine Ridge and possibly identify winter-use sites on public land to reduce depredation.

Model Variables Explaining Winter Elk-Use Sites

Realistically, elk select use sites based on several factors simultaneously, instead of evaluating each habitat component separately. The preference of one habitat component could depend on the presence of other habitat features. We measured 18 habitat variables to increase our perception of what is really being selected by elk on winter-use sites. We found that on average, elk in the Pine Ridge are four times more likely to use an elk-use site over a randomly located site (mean value for the Selection Function Ratio = 4.1), given the characteristics measured at each site.

Macro-habitat Variables

Road Type

Female elk in the Pine Ridge selected wintering areas away from high-use roads (State Highways and gravel roads) that would provide repeated disturbance and cause repetitive flight responses. Elk in the Pine Ridge were 16% less likely to use a site as the distance from a high-use road increased by 1 km. Elk avoided low-use (two-track and logging roads) roads also. Elk were 2% less likely to use a site as the distance from a low-use road increased by 1 km. Our confidence level in predicting that elk avoid low-use roads is low. We measured two-track and logging roads as separate components, however there were no active logging sites on privately-owned land during the time we measured habitat selection, therefore both road types served the same purpose.

Several studies have identified disturbance factors associated with roads and road-use as important variables that effect elk distribution (Perry and Overly 1977; Rost and Bailey 1979; Thomas et al. 1979; Lyon 1979, 1983; Johnson et al. 2000; Rowland et al 2000). Rowland et al. (2000) reported that elk were strongly influenced by the relationship between habitat selection and the distance to open roads. They attributed avoidance to roads to seasonal differences in traffic volume, cattle interaction, recreational use, and increased research activities during the summer months.

Lyon and Jensen (1980) reported that elk showed an increase in activity and habitat use in areas with limited access to roads. They reported that elk security could be enhanced through road closures and traffic control and that an elimination of automobile traffic would increase elk-use of clear cuts. Johnson et al. (2000) reported similar results to our findings in that the distance to roads that received medium traffic was significant for both elk and mule deer, and they found that elk avoided high traffic roads also. In contrast to our results, Edge et al. (1987) reported that elk avoidance to human disturbance and roads was not apparent. They related the discrepancy to the local topography that created a barrier between the disturbance and the animal. The local roads had a low traffic volume.

Slope

Winter elk-use sites in the Pine Ridge were located in areas with surrounding hills that provided a barrier against wind, harsh weather, and human disturbance. Typically, winter elk-use sites were positioned on midslope (67%) or topslope (24%) areas averaging 16% (range = 10-25%). As the slope of an elk-use site increased by one degree, the probability of that site being used increased by 22% (Table 2). Elk that use mid to topslope positions may benefit by having greater sight distance, thus improving their abilities to detect predators or other threats and reducing unwanted flight responses. Skovlin (1982) reported that it was easier to approach elk undetected from an upslope position rather than downslope.

Another possible reason that elk chose sites that provide increased slopes is the availability of forage. In the winter, steeper slopes with south facing aspects are the first to provide quality vegetation because of the moisture runoff that affects the local vegetation, suggesting that elk in the Pine Ridge were selecting steeper sloped areas for available forage. Slope affects the behavior of elk by determining the microclimate and plant composition (Skovlin 1982). Julander and Jeffery (1964) reported that elk selected foraging sites in relation to slope. Elk moved up the slope of hillsides because of the extended length of daylight, direct solar radiation, and shallower snow depths.

Other research has shown that slope is an important factor in habitat selection. Rowland et al. 2000 reported that elk selected sites with increased slope as distance to roads increased. Skovlin (1982) reported that elk frequented areas with slopes ranging from 0 – 40% and preferred areas that ranged from 15 – 30%. Julander and Jeffery (1964) reported that the greatest proportion of sites used by deer and elk were areas with slopes from 30 – 40%. Rice (1988) reported that elk in the Black Hills selected forested habitat interspersed with small openings with slopes that ranged from 0 – 15%. Contrary to our results, he found that elk-use decreased as the slope increased. Edge et al. (1987) reported that slope was the most important discriminating variable in there analyses. Elk in Montana preferred gentler slopes compared to randomly located sites, and the slope variable was eliminated from further analysis so it would not mask the contribution of other less important variables. In Idaho, Hershey and Leege (1982) reported that areas with slopes $< 20\%$ were used in excess of their availability and that slopes $> 60\%$ were avoided.

Distance to Edge

Elk in the Pine Ridge typically selected wintering sites on average 286 m from the edge of 2 habitat types (Table 2). Elk-use sites in the Pine Ridge were secluded areas that provided ponderosa pine habitat, interspersed with small grassland openings. We found as the distance to edge increases by 10 m, the probability of elk selecting the preferred site increases by $\leq 4\%$. The Pine Ridge is distributed with small openings that provide abrupt changes in edge. Skovlin (1982) reported that ecotones provide a desirable feature because of the enhanced gradient in moisture caused by soil depth, snow retention, and drying conditions from shaded-tree areas offering a diversity of plant communities and quality forage for elk. Small openings available in the Pine Ridge offer elk feeding opportunities year-round access because of the direct solar radiation. Elk in the Pine Ridge take advantage of these sites for foraging, while bedding areas are located in deeper forested areas.

Rice (1988) reported that elk in the Black Hills used similar strategies by using small grassland openings year-round with increased percentages of edge. In contrast to our results, He further observed that elk-use decreased with increased distance to edge. Elk in the Black Hills rarely ventured more than 90 m from the forest edge in the summer, spring, and fall, suggesting that hiding cover was an important habitat component in addition to forage availability. During the winter however, elk used foraging sites in the middle of open meadows, 0.4 km from forested areas.

Hiding Cover

Hiding cover consists of vegetative or topographic terrain features, or a combination of these features, that allow elk to avoid detection from predators and other disturbances, or escape when detected (Brown 1987). Elk in the Pine Ridge used the available forested cover and tall grassland vegetation in CRP fields, gullies, or changes in slope to avoid detection. Elk-use sites had a greater percentage of hiding cover ($\bar{x}$ = 58%, range = 30 – 83%) then randomly selected sites ($\bar{x}$ = 43%, range = 0 – 82%). The likelihood of elk using a winter site increased by $\leq$ 9% as the percentage of hiding cover increased by 10%, suggesting that hiding cover is a selected habitat feature for elk-use sites

Several studies have identified that hiding cover is an important habitat feature to elk distribution (Black et al. 1976, Irwin and Peek 1979, Skovlin 1982, VerCauteren and Hygnstrom 1998). Security cover appears to be required by elk in the presence of human disturbance (Peek et al. 1982). Human disturbance may be seasonal or short in duration, like the harvesting of crops, hunting, non-hunting recreational uses, or interaction with domestic livestock.

Black et at. (1976) suggested that elk-logging guidelines include leaving stands of timber up to 24 ha in size to provide security cover. Irwin and Peek (1979) reported that elk in northern Idaho used timbered areas greater than 30 ha, yet when roads were left open during hunting seasons, elk were displaced to areas with even more extensive cover. Skovlin (1982) reported that elk need adequate areas that provide dense escape cover as an essential part of their home ranges to avoid continuous, repetitive flight responses caused by hunting. He suggested that without adequate cover, elk expend too much energy and subsequently lose weight, endangering their well being as they enter winter.

VerCauteren and Hygnstrom (1998) reported the mean size white-tailed deer home ranges were not affected by muzzleloader hunting, however hunters flushed deer to parts of their home range in which hunting was prohibited. Mushroom hunters, agricultural activities, and muzzleloader hunters flushed non-migratory deer from their home range areas but they usually returned by the next morning.

Edge (1982) found that elk in Montana moved more than 2,000 m to avoid hunting pressure and often this flight distance included a topographic barrier between the disturbance and the animal. Rice (1988) reported that the greatest disturbance to elk in the Black Hills was hunting. During the hunting season, topographic features did not provide sufficient cover. Elk used only thick dense stands of ponderosa pine with 100% canopy cover. Road access provided repeated disturbance by hunters and only dense escape cover prevented repetitive flight responses.

MANAGEMENT IMPLICATIONS

These models were generated from habitat characteristics associated with winter elk-use sites. Further research is needed to potentially identify winter elk-use areas on private or public land that could be protected through land acquisitions, conservation easements, or land management plans. We suggest that these models be incorporated with a geographic information system to evaluate the suitability of the winter habitat available in the Pine Ridge.

The NGPC and the RMEF recently purchased 720 ha of prime winter elk habitat in the Bordeaux Creek study area, in which three known winter elk-use sites were located. These sites will be protected and enhanced for the long-term benefit of wintering elk and other wildlife.

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Table 1. Macro- and microhabitat variables measured at elk-use and random locations in the Bordeaux and Hat Creek areas, Nebraska, 1995-1997.

	Average Slope (%)	Average Canopy Cover (%)	Percent Hiding Cover	Basal Area	Aspect	Slope Position	Road Type	Edge Type	Distance to Edge (m)	Trees	Distance to Road (km)	Distance to Water (km)
Elk-Use							2 Track (76%)	Cropland (0%)				
						Top (24%)	Log Trail (19%)	Pine (52%)				
Mean	x = 16	x = 34	x = 58	x = 79.5	x = 161	Mid (67%)	Gravel (5%)	Pasture (43%)	x = 286	Mature (50%)	x = 1.41	x = 0.79
Range	(10-25)	(12-66)	(30-83)	(20.5-281)	(0-332)	Bottom (9%)	Highway (0%)	Deciduous (5%)	(3-1600)	Mix (50%)	(0.10-2.74)	(0.30-1.63)
Random							2 Track (71%)	Cropland (2%)		Pole (5%)		
						Top (23%)	Log Trail (11%)	Pine (68%)		Mature (30%)		
Mean	x = 12	x = 22	x = 43	x = 40.3	x = 164	Mid (59%)	Gravel (16%)	Pasture (25%)	x = 139	Mix (48%)	x = 1.08	x = 0.80
Range	(2-28)	(0-71)	(0-82)	(0-142.5)	(0-349)	Bottom (18%)	Highway (2%)	Deciduous (5%)	(0-500)	Seedling (0%)	(0.14-3.10)	(0.01-2.44)
										No Trees (18%)		

Table 2. Macro- and microhabitat variables measured at elk-use sites in the Bordeaux and Hat Creek areas, Nebraska, 1995-1997.

	Average Slope (%)	Average Canopy Cover (%)	Percent Hiding Cover	Basal Area	Aspect	Slope Position	Road Type	Edge Type	Edge Distance (m)	Trees	Road Distance (km)	Distance to Water (km)
Bordeaux Creek												
Elk Use 1	11	12	34	20.5	210	midslope	2 track	pine	300	mature	0.67	0.28
Elk Use 2	13	19	30	39.5	332	midslope	2 track	pine	60	mixture	1.8	0.99
Elk Use 3	10	33	73	63.5	124	topslope	2 track	pine	65	mixture	2.13	1.01
Elk Use 4	18	21	60	46.5	130	midslope	2 track	pine	320	mixture	2.28	0.88
Elk Use 5	18	47	70	120.5	130	midslope	2 track	pasture	80	mixture	0.95	0.79
Elk Use 6	15	38	65	72.5	190	midslope	logtrail	pine	40	mature	2.74	1.22
Elk Use 7	10	26	32	42.5	0	bottom	2 track	pasture	500	mixture	1.55	1.01
Elk Use 8	18	51	66	103.5	80	midslope	2 track	pasture	300	mature	1.3	0.48
Elk Use 9	17	66	83	129.5	250	topslope	logtrail	pasture	20	mixture	2.23	0.44
Elk Use 10	10	21	56	48.5	320	midslope	2 track	pasture	20	mixture	1.02	0.711
Hat Creek												
Elk Use 1	23	43	47	70.5	98	midslope	2 track	deciduous	250	mature	0.44	0.21
Elk Use 2	25	25	70	44	112	bottom	2 track	pine	20	mature	2.69	1.63
Elk Use 3	14	15	49	46.5	92	midslope	2 track	pine	20	mixture	0.89	1.2
Elk Use 4	16	59	70	147	180	topslope	logtrail	pasture	200	mature	1.77	1.18
Elk Use 5	25	54	70	98	120	topslope	2 track	pine	3	mature	0.1	0.3
Elk Use 6	21	28	53	49.5	166	midslope	2 track	pine	370	mixture	0.34	0.44
Elk Use 7	14	12	33	281	136	midslope	2 track	pine	130	mature	0.67	1.17
Elk Use 8	14	40	69	71	220	topslope	logtrail	pine	950	mixture	0.75	0.75
Elk Use 9	11	46	70	75.5	180	midslope	2 track	pasture	500	mature	3.42	0.59
Elk Use 10	19	40	63	67	149	midslope	gravel	pasture	1600	mixture	0.75	0.81
Elk Use 11	16	20	58	33	159	midslope	2 track	pasture	250	mature	1.15	0.56

Table 3. Significant variables, AIC, H & L P- values, odds ratios, resource selection function (RSF) ratios, and individual P- values of the 2 selected models of elk wintering areas in northwestern Nebraska, 1994-1997.

Model	Variable	R^2	AIC	H & L P- Value	Odds Ratio	RSF Ratio	P
1	Road 1	0.27	70.73	0.85	0.016	4.1	0.078
	Road 2				0.996		0.996
	Slope				1.225		0.005
	Distance to Edge				1.004		0.015
2	Road 1	0.28	72.54	0.96	0.017	4.1	0.088
	Road 2				0.929		0.932
	Slope				1.201		0.028
	Distance to Edge				1.004		0.017
	Hiding Cover				1.009		0.664

Table 4. The top 10 models generated with their corresponding AIC.

Model	**AIC**
Road 1, Road 2, Slope, Distance to Edge	70.7
Road 1, Road 2, Slope, Distance to Edge, Hiding Cover	72.5
Slope, Distance to Edge	74.3
Slope, Basal Area, Distance to Road	74.5
Slope, Distance to Edge, Hiding Cover	75.1
Basal Area, Distance to Road	75.8
Distance to Edge, Hiding Cover	75.9
Slope, Basal Area	76.0
Basal Area, Hiding Cover	76.1
Slope, Hiding Cover	76.3

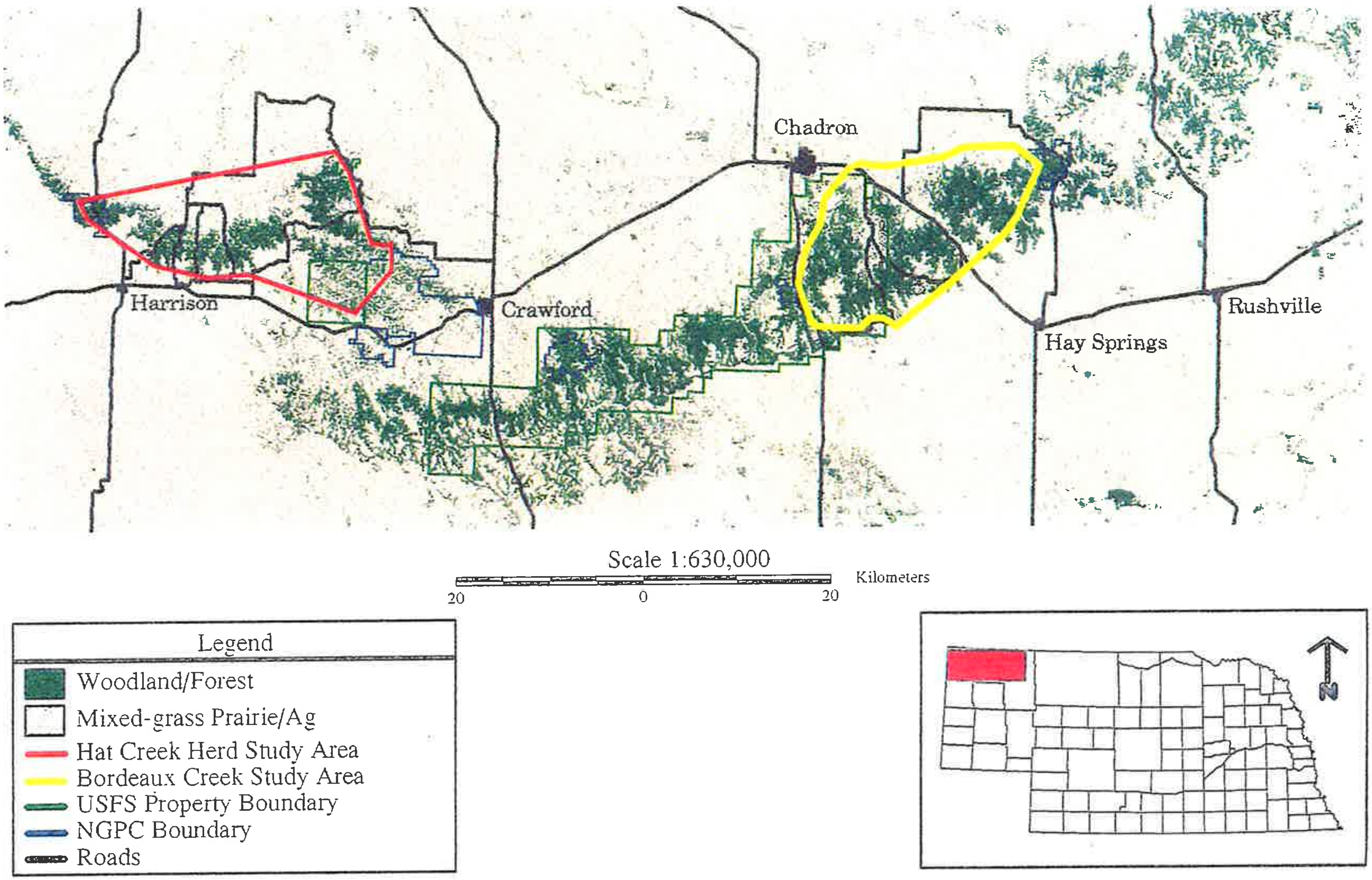

Figure 1. Pine Ridge region of northwestern Nebraska.

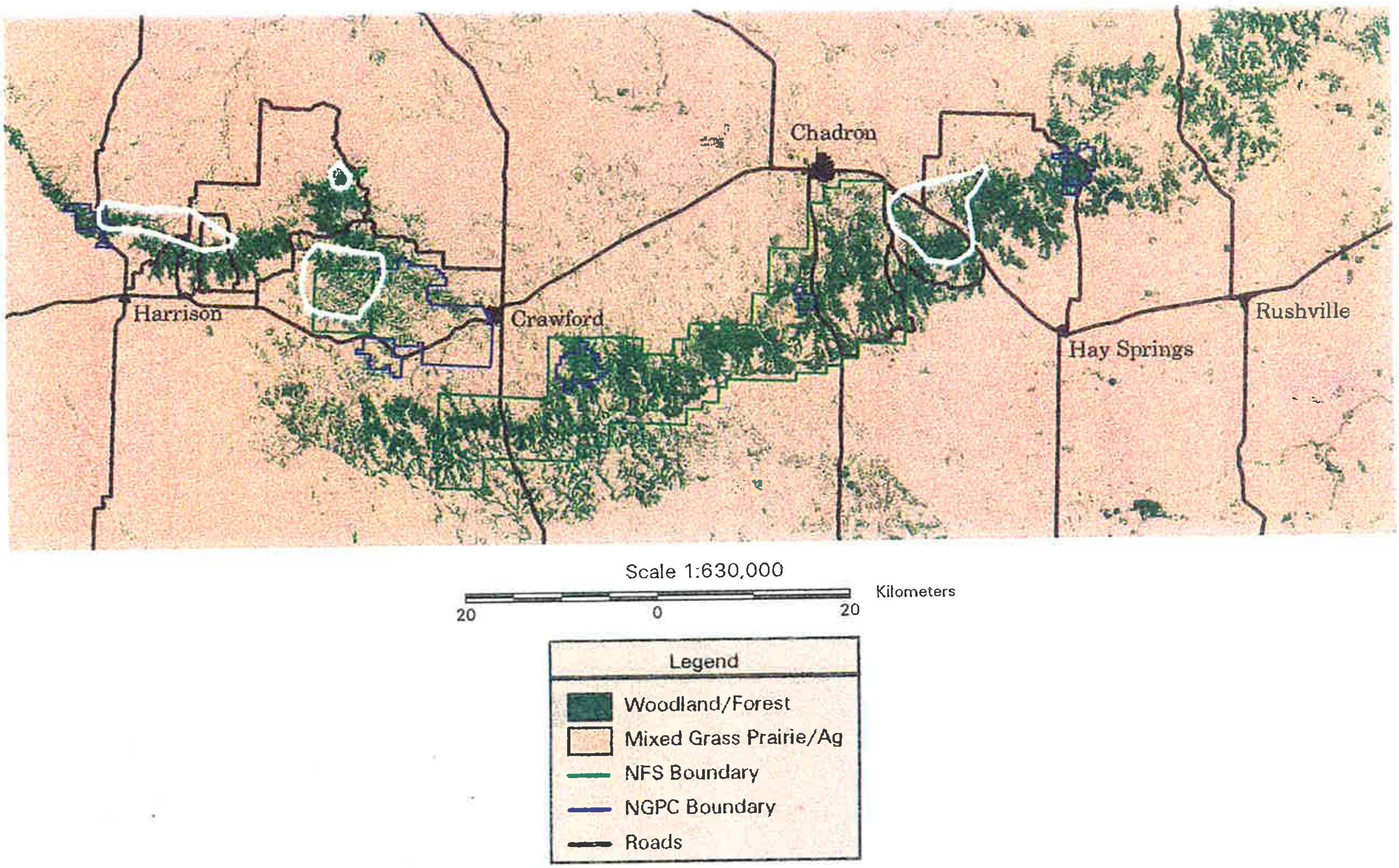

Figure 2. Elk herd home ranges during winter in the Bordeaux and Hat Creek study areas of Nebraska, 1996-1997.

CHAPTER 4:

SURVEILLANCE OF SIX DISEASES OF FREE-RANGING ELK IN NEBRASKA

Abstract: We collected blood samples from 21 captured cow elk (Cervus elaphus nelsoni) and 65 harvested elk from three separate study areas in Boyd, Dawes, and Sioux counties of Nebraska, during 1995 to 1997. We tested for six infectious diseases that commonly infect wild ruminants and domestic livestock. No titers were found present for anaplasmosis, bluetongue (BT), or brucellosis. Antibodies for Leptosira interrogans bratislava (8 of 86, 9%) and L. i. hardjo (7 of 86, 8%) were present from all three-study sites. We found antibodies for epizootic hemorrhagic disease (EHD) (2 of 86, 2%) and bovine viral disease (BVD) (3 of 86, 3%) in samples from Dawes and Sioux counties. The low percentage of exposed elk in the sample and the low antibody titer ratios (1:100 to 1:400), suggest that previous exposure to infectious organisms may have occurred, but none of the three populations have active infections.

INTRODUCTION

Livestock and free-ranging wildlife have shared common grazing areas in the Intermountain west since the encroachment of European settlers. The threat of disease transmission between elk and cattle probably first occurred after the Greater Yellowstone Area (GYA) was settled. Early elk-cattle conflicts in the GYA were over forage harvested from traditional elk wintering grounds to provide feed for cattle during winter.

This, coupled with settlers bringing cattle to the region that were unknowingly infected with transmittable diseases, like brucellosis, and the Wyoming Legislature in 1910 creating a temporary elk feedground (Boyce 1989), resulted in artificial crowding of elk and a high rate of exposure to transmittable bovine diseases. Disease transmission probably occurred as elk and cattle shared the same wintering areas and fed together in cattle feedlines (Thorne et al. 1997).

Disease transmission between wildlife and domestic livestock has caused economic and political conflict for both ranchers and wildlife managers alike. In the past, serologic testing of wildlife populations have provided surveillance of selected zoonoses (Trainer and Hoff 1971), discovered infectious agents (Parks and England 1974), and determined how the transmission of disease occurs between wildlife and domestic animals (Chow and Davis 1964). Our study was designed to provide the Nebraska Game and Parks Commission (NGPC) with an initial surveillance of six shared diseases between elk and cattle. We sampled elk for antibody titers against brucellosis, leptospirosis, anaplasmosis, EHD, BT, and BVD.

Anaplasmosis is economically devastating to the cattle industry. A survey of bovine diseases by the American Cattlemen's Association placed anaplasmosis fourth among the top ten diseases (Peterson et al. 1973), resulting in an economic impact of $3.5 to 7 million dollars in damage to the cattle industry. Anaplasmosis is caused by the intraerythrocytic rickettsial agent (Anaplasma), which is commonly transmitted through shared vector-borne hematophagous arthropods such as ticks and biting flies (Kuttler

1984). Uterine transmission is also possible (Zaugg and Kuttler 1984). A. marginale is a pathogenic agent that infects cattle and elk while A. ovis is known to infect domestic sheep and elk (Hagan and Bruner 1988; Kuttler 1984; Post and Thomas 1961). Other wildlife in the Pine Ridge that is susceptible to (Anaplasma) include bighorn sheep (Ovis canadensis canadensis) (Howe et al. 1964), bison (Bison bison) (Zaugg 1986), pronghorn (Antilocapra americana) (Jacobson et al. 1977; Zaugg 1987), mule deer (Odocoileus hemionus), and white-tailed deer (O. virginianus) (Howarth et al. 1969; Howe and Hepworth 1965; Kreier and Ristic 1963).

In the Pine Ridge region, cattle and domestic sheep share the same pasturelands as elk and other wildlife. Deer may act as a reservoir for anaplasmosis (Christensen et al. 1960), and elk are known to carry A. marginale and potentially act as a reservoir for up to one year in free-ranging conditions (Kuttler 1984: Jacobsen et al. 1977). For these reasons, it is important to monitor the status and detect any local outbreaks of anaplasmosis in the region.

Hemorrhagic disease is caused by the genus (Orbivirus), which is the same agent for both BT and the EHD virus (Patton et al. 1994). Elk, bighorn sheep, moose (Alces alces), mule deer, black-tailed deer (Odocoileus hemionus) and white-tailed deer are all susceptible to hemorrhagic disease (Robinson et al. 1967; Trainer and Jochim 1969; Hoff and Trainer 1981; Johnson et al. 1986; Thorne et al. 1988). Hemorrhagic disease is transmitted by biting midges from the genus (Culicoides spp.) and symptoms or signs in elk are mild and similar to other diseases, making it difficult to diagnose BT or EHD during suspected outbreaks.

Bovine virus diarrhea is a contagious disease caused by the genus (Pestvirus). Cattle may be infected with both cytopathogenic and noncytopathogenic strains of BVD, allowing secondary infections to occur and acute life threatening mucosal disease (Hagan and Bruner 1988). Wildlife in the Pine Ridge that is susceptible to BVD includes mule deer (Stauber et al. 1977; Couvillion et al. 1980), white-tailed deer (Kahrs et al. 1964), bighorn sheep (Parks et al. 1974), pronghorn (Barrett and Chalmers 1975), bison (Williams et al. 1993), and elk (Hagan and Bruner 1988).

Serologic studies suggest cattle densities or pasture stocking rates are an important factor in the transmission of BVD. Free-ranging deer that occupy the same pasture may become infected with BVD without having contact with cattle (Frolich and Hofmann 1995). Past serologic surveys for BVD in cattle have estimated a 73% seropositive rate of infection in Nebraska, where 100 or more animals were tested (Newberne et al. 1961). Further surveys have shown a 70 to 80% seroprevalence in cattle in the United States (Ames 1986).

Brucellosis is caused by the genus (Brucella). Elk are susceptible to brucellosis as are bison, (Jessup and Boyce 1996, and Thorne et al. 1978), mule deer, white-tailed deer (Trainer and Hanson 1960), moose (Fenstermacher and Olsen 1942, Jellison et al. 1953) and pronghorn (Thorne et al. 1979). Brucellosis infections have also been reported in axis or chital deer (Axis axis) of India, which are now a common free-ranging exotic species in Texas (Nielsen and Duncan 1990).

Transmission of brucellosis may occur by intraspecific or interspecific pathways (Williams et al. 1997). The natural act of an elk licking the fetus and ingesting the fetal membranes or vaginal secretions is the most common form of transmission (Jessup and Boyce 1996). The bacterial strain B. abortus can be present in the reticuloendothelial tissue of the udder and may spread to calves through the nasopharynx and conjunctivae (Hagan and Bruner 1988).

The brucellosis eradication program administered by the USDA, Animal and Plant Health Inspection Service (APHIS) has had tremendous success in eradicating the disease from domestic livestock in the United States but not without a considerable expense to the industry. The cattle industry has spent approximately $3.5 billion (King 1997) to eradicate and isolate what is thought to be the last reservoir of B. abortus in bison and elk located in the GYA.

Leptospirosis is a bacterial agent with more then 150 strains, but only one serotype (L. interrogans) (Kistner et al. 1982). This disease is commonly found in cattle (Jessup and Boyce 1996) and can be transmitted between cattle and free-ranging wildlife when common pasture is shared (Adrian and Keiss 1977). Elk may act as a reservoir and potentially carry the disease to infect livestock and humans (Kistner, et al. 1982). Other wildlife susceptible to leptospirosis includes pronghorn (Thorne et al. 1982), mule deer, (Jessup and Boyce 1996), and white-tailed deer (Davidson et al. 1981).

Nebraska Elk

Elk were extirpated from Nebraska in the 1880s, but reappeared in the Pine Ridge region of the state during the 1960s, presumably from immigration from the Rawhide Butte area in eastern Wyoming. Population levels of elk were estimated to be 150-200 in the Pine Ridge area (Stillings 1999) and 25-40 in the Boyd County area (Grier 1995) during the period when this study was conducted (1995-1997). The natural reoccurrence of elk along with the heightened awareness of disease transmission between domestic livestock and elk has prompted the NGPC to develop an Elk Management Plan (NGPC 1995). The plan recognized elk as a native fauna of Nebraska and a valuable component, particularly to the Pine Ridge area and it calls for the NGPC to monitor the overall health of elk populations in the state and to prevent contamination of domestic livestock through the removal or treatment of infected elk. In the past, serologic surveys in Nebraska have monitored disease outbreaks in wildlife populations of white-tailed deer and pronghorn (Wilhelm and Trainer 1966; Johnson et al. 1986) and provided surveillance of selected zoonoses but there has never been a study to monitor select disease antibodies in free ranging elk in Nebraska. The objective of this study was to determine the prevalence of six diseases in Nebraska elk and provide a baseline serologic sample from three separate elk herds in the state.

STUDY AREA

Serologic samples were collected from free ranging elk in two distinct areas of Nebraska. The Pine Ridge region is located in the northwest section of the panhandle and Boyd County is located in the north central section of the state (Figure 1).

The Pine Ridge region is a unique timbered area of eroded limestone that extends from Wyoming through the Nebraska panhandle and into South Dakota. In Nebraska, the Pine Ridge is approximately 160 km long and 8 km wide in an easterly to northeasterly direction through Sioux, Dawes, and Sheridan counties (Nixon 1967).

Two distinct elk study areas exist in the Pine Ridge. The Hat Creek Unit is located between Harrison and Crawford, and the Bordeaux Unit is located east of Chadron. Together both study units contain the largest population of elk in the state. Approximately 150 animals reside in the Pine Ridge. Livestock ranching is the primary agricultural enterprise throughout the entire region. Most ranches produce feeder calves and lambs along with winter wheat, alfalfa, and oats. Recently, some ranchers in the Pine Ridge have diversified their operations by raising elk or bison.

The Pine Ridge is the largest area of ponderosa pine (Pinus ponderosa) woodland in Nebraska (384,000 ha) (Tolstead 1947; J. Abegglen pers. commun. 2000). The United States Forrest Service (USFS) Nebraska National Forest (NNF) administers approximately 20,235 ha of land in the Pine Ridge while the NGPC manages approximately 10,118 ha of land throughout the area.

The Boyd study unit is located in Boyd County, Nebraska and Gregory County, South Dakota (Figure 1). This study area lies between the Missouri River watershed and the Niobrara River watershed. Boyd County is dominated by farmland. Winter wheat, corn, and feeder cattle are the primary products. Approximately 22 to 40 elk reside in the Boyd county study unit (Grier 1995). In 1996 and 1997 the NGPC, along with the South Dakota Game and Fish, implemented a hunting season in Boyd County, NE and Gregory County, SD to reduce crop depredation caused by the elk in the region.

METHODS

Capture and Sera Sampling

From 1995 to 1997, sera samples were collected from 21 captured cow elk and 65 harvested elk in the three elk study areas mentioned. Elk were captured by helicopter net-gunning (Helicopter Wildlife Management Company, Salt Lake City, UT) and modified Clover traps (Clover 1956) in the Hat Creek and Bordeaux Units. We collected blood samples from each of the captured elk with two 10-cc red stopper vacutainer tubes and one anticoagulant 10-cc purple stopper ethylenediamine tetraacetic acid (EDTA) vacutainer tube. Samples were labeled and kept cold (not frozen) in a cooler with frozen cool packs. The samples were delivered to Dr. Roger Sahara, Veterinary Field Officer for the Nebraska Department of Agriculture Bureau of Animal Industry, within three hours of collection.

In addition, blood collection kits with field instructions were sent to permit holders for the 1996 and 1997 elk hunting seasons. Each hunter was instructed to collect two 10-cc vacutainer tubes of blood from the elk they harvested at the time it was field dressed. Harvested animals were then registered at mandatory check stations and blood samples were collected. Each blood sample was labeled with an identification number and stored in a cooler with frozen cool packs until they were delivered to Dr. Sahara's office. We also collected one incisor tooth from each elk for aging, and measured the total body length of the animal, shoulder height, neck girth, heart girth, brisket fat, and body cavity fat. Other data recorded included the identification number, hunter information, date and time of the kill, and the sex and estimated age of the harvested elk.

Blood samples were centrifuged at 500 X G for 10 minutes, and the serum was decanted into individual sterile vials. We sent 3-ml of serum from each 10-cc red vacutainer tube to the Nebraska State Brucellosis Laboratory in Lincoln for analysis. Sera samples were tested for brucellosis using the Particle Concentration Fluorescence Immunoassay (PCFIA) Test, the Card Test, Rivanol Test, and the Plate Agglutination Test. The remaining 2-ml of sera from each original 10-cc red vacutainer tube was placed in separate sterile tubes and forwarded to the Panhandle Veterinary Diagnostic Laboratory in Scottsbluff, NE. These samples were stored for future testing if needed.

The 5-ml of blood from the second 10-cc red stopper vacutainer tubes were centrifuged and decanted into individual sterile vials. These vials were forwarded to the South Dakota Veterinary Diagnostic Laboratory (SDVDL) in Brookings, SD, and tested for L. interrogans serovars (L. i. pomona, L. i. hardjo, L. i. icterohaemorrhagiae, L. i. canicola, L. i. grippotyphosa, and L. i. bratislava) using the Micro-Agglutination Test.

Sera samples were also tested at SDVDL for Anaplasma marginale using the Complement Fixation Test, BT virus by the Agar-Gel Immunodiffusion Test and BVD by the Serum Neutralization Test. Sera samples were further tested for EHD using the Agar-Gel Diffusion and Immunofluorescent Antibody tests. Positive or negative titer results were recorded. The University of Nebraska Institutional Animal Care and Use Committee (IACUC # 94-09-075) approved all aspects of this study.

RESULTS

The antibody prevalence of the six diseases surveyed from all three-study sites was very low (Figure 2). All 86 animals tested from the Bordeaux, Hat Creek, and Boyd Units during the three-year study were negative for anaplasmosis, bluetongue, and brucellosis (Table 1).

Elk bulls and cows were seropositive to leptospirosis in all three-study areas. Two strains of leptospirosis, L. i. bratislava (8 of 86, 9%) and L. i. hardjo (7 of 86, 8%), were detected in 1995 and 1996, but no seropositive results were found in 1997. Titer ratios ranged from 1:100 to 1:400, for both strains detected in all three units surveyed.

Elk were seropositive to BVD only in 1995 in the Bordeaux and Hat Creek Units. Two cows and one bull tested seropositive with antibody titer ratios ranging from 1:8 to 1:128 (Table 1).

Elk were seropositive to EHD in 1995 in both the Bordeaux and Hat Creek Units. One bull tested seropositive in the Bordeaux Unit and one bull tested seropositive in the Hat Creek Unit (Table 1).

DISCUSSION

We found there were no titers present for anaplasmosis, BT, or brucellosis. Seropositive results were relatively low and considered minimal for Leptosira interrogans bratislava, L. i. hardjo, EHD, and BVD. Results indicate that the sampled elk in the Pine Ridge and Boyd County study areas have been previously exposed to only three of the six diseases surveyed and there is minimal risk that these animals are active carriers or infectious to the elk population.

Serology can be an important tool in understanding the etiology of a disease (Taylor et al. 1997). The presence of detectable antibodies in a serum sample reveals that the tested animal has been exposed to a particular antigen at some point in its life and has produced an antibody to that disease. Detection does not mean that the animal is a carrier, or that it is currently spreading the disease throughout the population.

Negative sera results for anaplasmosis indicate that the elk sampled from the herd had not been previously exposed to the pathogenic genus Anaplasma. The absence of positive titers from the sampled elk indicates that during the study period there were no carriers of A. marginale from the samples taken. These results further suggest that all three populations surveyed were free of infected carriers at the time the study took place, and most likely anaplasmosis is not a current health risk to the elk in the Pine Ridge and Boyd Units.

The absence of anaplasmosis from the surveyed elk may be explained by the vector-borne arthropods in the region. Regional serologic surveys for anaplasmosis in white-tailed deer in the Southeastern part of the United States found that one known tick (Dermacentor albipictus) out of four species commonly found in the region could biologically transmit rickettsemisas, while the others could not (Keel et al. 1995). The absence of a tick vector in the region was thought to dramatically reduce the role of white-tailed deer becoming carriers of the disease.

Another limiting factor is the mechanical transmission by biting flies (Tabanid spp.). Mechanical transmission of A. marginale is less efficient than biological transmission by ticks (Kuttler 1981). Rickettsemisas are necessary for biting flies and ticks to transmit A. marginale to susceptible hosts (Wilson and Meyer 1966). Multiple bites are also necessary for A. marginale to be transmitted by biting flies to the host because of the small amount of blood exchanged and the time period the disease is viable ($\leq$ 5min) on the mouthparts of the insect (Howell et al. 1941). Multiple bites however are counterproductive to disease transmission because they increase the circulation and pool the blood (Keel et al. 1995). In addition, most white-tailed deer in the region use pastures at night when tabanids are inactive versus during the day when domestic livestock commonly gather at watering areas (Keel et al. 1995).

A similar situation exists in the Pine Ridge and Boyd County. Cattle, during the hot summer and early fall months tightly group around windmills and common watering areas throughout the late morning and afternoon hours of the day. Elk use these pasture areas at night, or in cool early mornings, when biting flies are less active. Elk have also been shown to avoid cattle throughout the Pine Ridge region (Stillings 1999). Elk densities in the Bordeaux, Hat Creek, and Boyd Units are relativity low compared to the carrying capacity of the areas. The low elk densities in all three units, along with relatively healthy cattle reduce the chance of close interaction and an opportunity for vector-borne insects to transmit anaplasmosis from one host to another.

Hemorrhagic disease antibodies from the EHD virus were present in the Bordeaux and Hat Creek Units (one animal per unit), but were absent in the Boyd County Unit. Positive results were found only in the first year surveyed. Transmission of BT and EHD is through biting midges (Culicodes spp.) (Gibbs et al. 1983) and outbreaks are limited to the warmer months and cease with the first killing frost (Kistner et al. 1982).

Negative sera results for BT indicate that the elk sampled had not been previously exposed to the BT virus. The absence of BT antibodies from the sampled sera indicates that during the study period there were no carriers of the BT virus from the elk sampled. These results further suggest that all three populations surveyed were free of infected carriers at the time the study took place, and most likely BT is not a current health risk to the elk in the Pine Ridge and Boyd areas.

Positive sera results for EHD indicate that the two elk sampled from the Bordeaux and Hat Creek Units had been previously been exposed to the EHD virus sometime in their lives. However, only two animals tested positive out of 33 samples taken (6%) taken the first year and no further positive results were found during the survey. Results suggest that the two positive elk are not carriers of EHD and they present a minimal health risk to the populations sampled (R. Sahara pers. commun.). Periodic outbreaks of

EHD have occurred in white-tailed deer throughout Nebraska. Seropositive EHD results have been reported for white-tailed deer in Cherry County, which is adjacent to Sheridan County, and several counties along the Platte River (Wilhelm and Trainer 1966). For this reason, deer populations in the northern regions of the Sandhills and the Platte Valley have sufficient antibodies for EHD and the disease is considered enzootic to these areas of the state (Wilhelm and Trainer 1966). The exact source for the two positive sampled elk is not known, but cattle in the Pine Ridge at this time do not seem to be affected by the disease (R. Sahara pers. commun.).

We found brucellosis absent from the sera samples taken in our study. Negative results indicate that the sampled elk have not been previously exposed to the (Brucella) agent. Results suggest that all three populations surveyed were free of infected carriers at the time the study took place and most likely brucellosis is not a current health risk to elk in the state.

Brucellosis is a disease that has been given a tremendous amount of media coverage as a potential health and economic threat to domestic livestock. In northwest Wyoming brucellosis has been detected on most of the 23 elk feedgrounds and it is likely that brucellosis would not exist in elk in the absence of elk feedgrounds (Thorne et al. 1997). A pivotal event that brought brucellosis to the forefront of controversy with livestock production is a lawsuit filed in Wyoming for $1.13 million for damages attributed to elk and/or bison as bacterial sources of the disease.

One could conclude that the vigorous brucellosis eradication program maintained by the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) is a large reason for the absence of brucellosis in Nebraska. At the present time, Nebraska is a brucellosis-free state and the lack of infected livestock capable of spreading the disease limits the threat to elk.

We found two strains of leptospirosis in the three-study areas (1995-6%, n=33; 1996-42%, n=19; 1997-0%, n=34). Titer ratios ranged from 1:100 to 1:400. Survey results suggest the animals exposed to leptospirosis were infected sometime during their lives, but the low titer ratios along with the relatively low numbers of elk found positive in the sample indicate there were no infectious carriers at the time the three herds were tested (R. Sahara pers. commun.). To draw further conclusions, one would have to draw paired blood samples at least 30 days apart to determine if there was a spike in the antibody titer response (Sahara, unpubl. data).

Leptospirosis is a bacterial agent that does not need a vector-borne insect to be transmitted between cattle and elk. Carriers of the disease may shed the bacterium through their urine onto inanimate objects or into common watering areas. The bacterium can easily pass through and penetrate mucous membranes of the soft tissue areas like the mouth, nose, and eyes or exposed areas of the skin that have abrasions (Kistner et al. 1982). For this reason, elk and cattle sharing common pasture or rangelands may share the disease (Adrian and Keiss 1977) and this may be the case in all three areas studied.

Seropositive results for BVD were relatively low in frequency and considered minimal in all three years tested (1995-9%, n=33; 1996-0%, n=19; 1997-0%, n=34). Three elk sampled had been previously exposed to BVD. Titer ratios ranging from 1:8 to 1:128, suggest that they were not infectious carriers of the disease and at the present time the disease is not active in the herds tested (R. Sahara pers. commun.). To draw further conclusions about the results, one would have to draw paired samples taken at least 30 days apart to determine if there is a spike in antibody response (Sahara, unpubl. data).

Cattle in the Pine Ridge are often diagnosed with BVD, and one could suggest that the previous exposure to BVD came from cattle (R. Sahara pers. commun.). Bovine virus diarrhea is perpetuated through two cycles of transmission. One source is through persistently infected cattle that shed the virus through nasal secretions, saliva, blood, feces, and urine. The other is by vertical transmission through the cow's blood to the fetus (E. Williams pers. commun.). The virus may be shed for prolonged periods of time and is more prevalent in the late winter and spring.

Winter and spring are periods in the Pine Ridge when cattle producers supplement their livestock with high energy feed rations to further weight gains and prepare the pregnant cows for the calving season. Cattle are feed in pastures located close to the stored feed (usually close to the main buildings) that also provides sheltered areas in adverse weather conditions. Supplemental feeding in protected areas help cattle avoid the cold and wet weather while promoting weight gain and enhancing animal condition, but this also increases animal contact and the risk of disease transmission. In addition, elk may become conditioned to using cattle feedlines because of the available high quality feed source and in return come in close contact with unknowingly infected cattle.

MANAGEMENT IMPLICATIONS

We recommend the NGPC continue to run serologic surveys on an annual basis. Anaplasmosis, BT, and brucellosis are currently absent from the samples surveyed, however, they could be present in the populations tested or they may appear in blood samples in the future. Leptospirosis, EHD, and BVD have been detected and it is critical to know the status of these transmittable diseases. Without previous, or at best minimal exposure, to the diseases mentioned, a low antibody resistance exists to the diseases tested. The introduction of one of the known viruses or bacterial agents could be catastrophic, resulting in an epizootic situation and cause irreversible consequences that could impact the entire elk population. Serological surveys should be continued on an annual basis from harvested elk.

The Bordeaux Creek study area had an elk feedground established from 1994 to 1997 by the NGPC to act as a supplemental feeding area to "hold" elk and prevent crop and hay depredation. The feedground was terminated in 1997 because of the potential for disease transmission. We support the termination of feedgrounds in the Pine Ridge. In 1999, the NGPC purchased the land (over 728 ha) that contained the original elk feedground. With the purchase of this land, greater opportunities exist in reducing landowner conflict and supporting elk habitat.

The NGPC Elk Management Plan recognizes the value of providing educational information and material. We recommend this objective be continued in the Pine Ridge and Boyd County areas to help reduce landowner depredation complaints. Crowding on feedgrounds, whether it is domestic livestock or wildlife, increases the chance of disease transmission to susceptible individuals in the herd or population.

We recommend that disease monitoring be expanded to address other health concerns that exist in the region. Elk farming is a relatively new economic enterprise that has developed in the Pine Ridge. During this study, ranchers throughout the Pine Ridge purchased game farmed elk without making the adequate modifications to their corrals and holding pen facilities. The possibility of escape is a great concern to wildlife managers (R. Sahara pers. commun.). At the present time Dr. Sahara and others are working with the Nebraska State legislature to tighten monitoring and entrance restrictions of exotic farmed animals.

Ranchers that run cow-calf operations purchase bulls annually to manage the genetics of the sire and the performance of the herd. Elk and bison ranching rely on the same management technique. The chance of an infected animal being brought into the area and the minimal antibodies shown in the sample surveyed could result in a epizootic environment for the free-ranging elk established in Nebraska.

We recommend further monitoring for other diseases in the region like chronic wasting disease (CWD). Chronic wasting disease was first discovered in captive mule deer (1967-79) in a Colorado wildlife facility outside of Fort Collins, Colorado and later was found in the Sybille Wildlife Research Unit in Wheatland, Wyoming. Chronic wasting disease has infected captive mule deer, black-tailed deer, and elk found in these research facilities. In 1981, CWD first showed up in the wild in southeast Wyoming and north central Colorado. About 100 cases of CWD have been reported in free-ranging mule deer, white-tailed deer, and elk since 1981.

Approximately 6% of the deer tested positive in Colorado and less than one percent of the elk tested positive for CWD in 1997. Wyoming had similar results among deer samples for the falls of 1997 and 1998. In 1998, 15 elk samples were tested from the region in Wyoming and no positive results were found (Madson 1998).

In 1998 the NGPC and the Animal and Plant Health Inspection Service (APHIS) examined 213 deer brain stems collected from west of Ogallala and south of Cody, NE and 32 brain stems from free ranging harvested elk in the Bordeaux and Hat Creek Units to survey for CWD. In addition, 72-farmed elk were also collected and tested in the Pine Ridge area for CWD. All 213 deer samples and 104 elk samples were negative to CWD (R. Sahara pers. commun.).

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Table 1. Titer ratios for six diseases in a sample of elk (n = 86) from Boyd, Dawes, and Sioux Counties, Nebraska, 1995-1997.

Location	Sex	n	Anaplasmosis	Bluetongue	Brucellosis	EHD[a]	BVD[b]	Leptospirosis
					1995			
Boyd Unit			No samples					
Bordeaux Unit	Male	3	Neg.	Neg.	Neg.	(1) Pos.	Neg.	Neg.
	Female	15	Neg.	Neg.	Neg.	Neg.	(1) Pos. 1:8[e]	(1) Pos. b 1:100[c]
Hat Creek Unit	Male	2	Neg.	Neg.	Neg.	Neg.	(1) Pos. 1:32	(1) Pos. b 1:100
	Female	13	Neg.	Neg.	Neg.	(1) Pos.	(1) Pos. 1:128	Neg.
					1996			
Boyd Unit	Male	4	Neg.	Neg.	Neg.	Neg.	Neg.	(2) Pos. b 1:100 h 1:400[d]
	Female	4	Neg.	Neg.	Neg.	Neg.	Neg.	(1) Pos. h 1:200
Bordeaux Unit	Male	2	Neg.	Neg.	Neg.	Neg.	Neg.	(2) Pos. b 1:100 h 1:100 b 1:200 h 1:200
	Female	5	Neg.	Neg.	Neg.	Neg.	Neg.	(1) Pos. b 1:100 h 1:400
Hat Creek Unit	Male	3	Neg.	Neg.	Neg.	Neg.	Neg.	(2) Pos. b 1:100 h 1:100 b 1:200 h 1:100
	Female	1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
					1997			
Boyd Unit	Male	4	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
	Female	2	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Bordeaux Unit	Male	3	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
	Female	8	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Hat Creek Unit	Male	11	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
	Female	6	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.

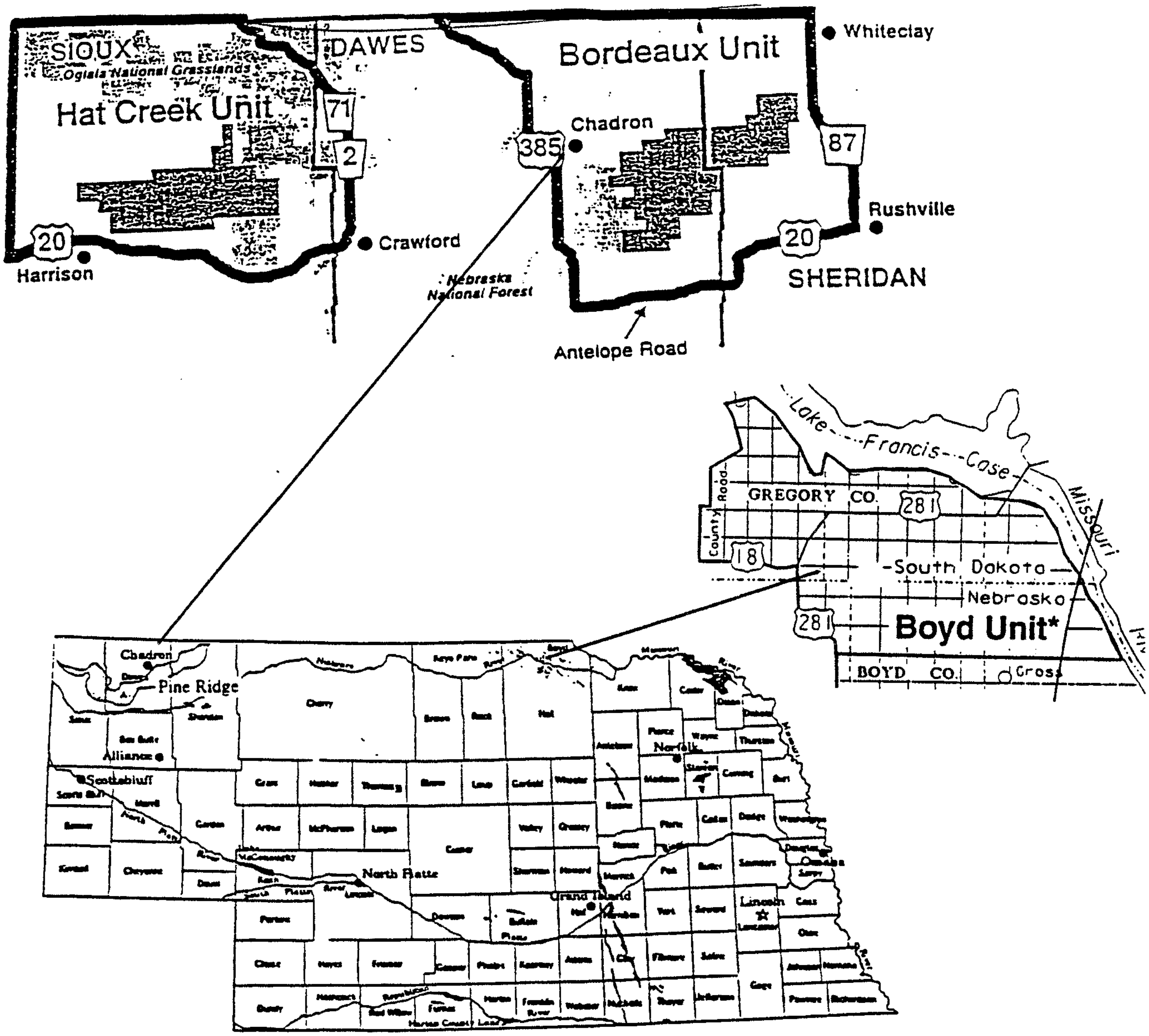
[a] EHD Epizootic Hemorragic Disease (EHD) [e] BVD titer ratio

[b] Bovine Viral Disease (BVD)

[c] L. i bratislava (b)

[d] L. i hardjo (h)

Figure 1. The Hat Creek, Bordeaux Creek, and Boyd County study areas in Nebraska where serologic samples were taken from 86 elk.



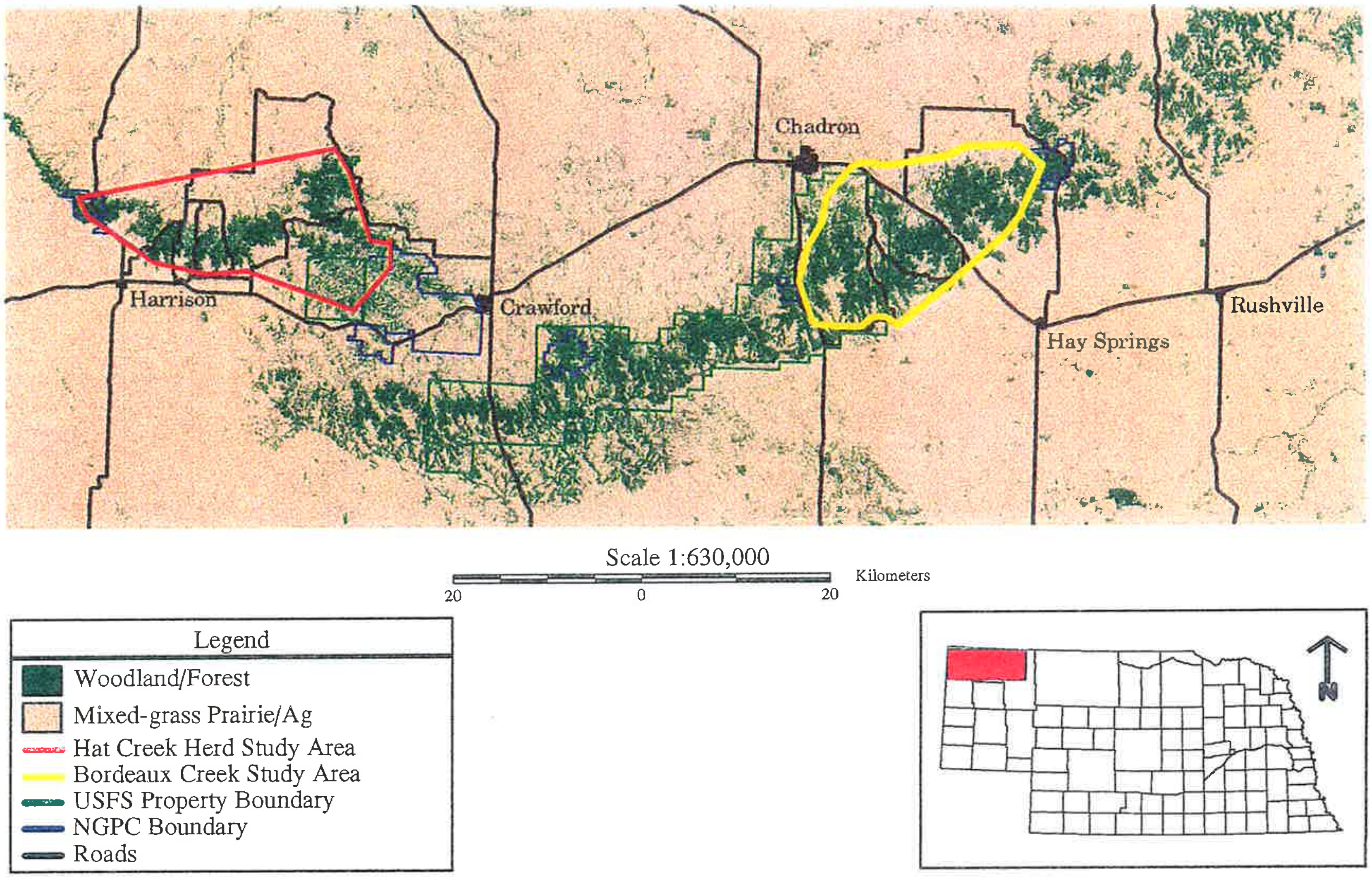


Figure 1. Pine Ridge region of Northwestern Nebraska.

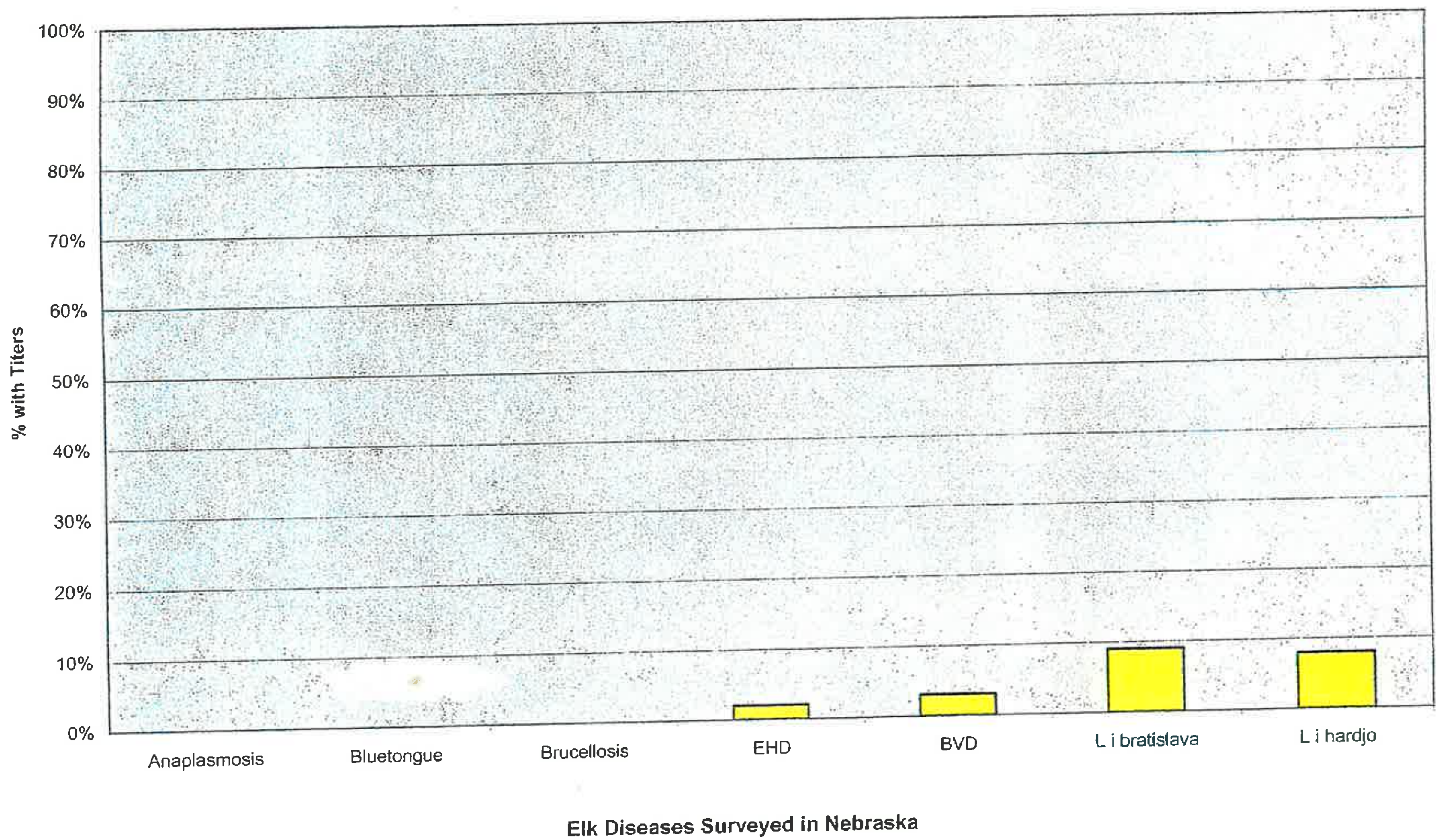


Figure 3. Percent of titers for six diseases in a sample of elk (n = 86) from Boyd, Dawes, and Sioux Counties, Nebraska, 1995-1997.